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THERMAL ANALYSIS OF AN IRRADIATED FUEL ROAD CASK FOR RECENTLY DISCHARGED FUEL UNDER NORMAL AND FIRE ACCIDENT CONDITIONS

Report No 87-249-K

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ABSTRACT

An existing three-dimensional finite difference heat transfer code has been extended to cover the thermal analysis of an irradiated fuel road cask for the transportation of Recently Discharged (RD) fuel under normal conditions and hypothetical fire accident conditions. The code was based on the numerical solution of the conservation equations of mass, momentum and energy. The temperature distribution within the cask cavity was obtained by modelling the cavity as two separate regions. The region occupied by the carbon steel liner/aluminum basket was represented by a solid medium with equivalent thermal properties. The remainder of the cavity was modelled as a pure fluid region. Good comparison between code predictions and existing experimental results has been obtained for heat input levels in the range of 200 to 700 W/Bundle. Results for the actual road cask containing RD fuel are also presented for 700 W/Bundle. The final design calculations for licensing purposes will be presented in other reports using the extended computer codes entitled TAN-RD and TAF-RD.

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EXECUTIVE SUMMARY

THERMAL ANALYSIS OF AN IRRADIATED FUEL ROAD CASK FOR RECENTLY DISCHARGED FUEL UNDER NORMAL AND FIRE ACCIDENT CONDITIONS

D. Taralis
Applied Mechanics Section
Mechanical Research Department

This report presents the extension and verification of a special purpose three-dimensional heat transfer computer code for the thermal analysis of a road cask for Recently Discharged (RD) fuel under normal and fire accident conditions. The results of this study include:

1. Comparisons of theoretical predictions with existing experimental results for a road cask containing RD fuel submerged in water (Water Cavity). The cask was tested with an impact limiter.

2. Representative temperature results for a RD road cask under normal and fire accident conditions.

The results of this study provide the necessary confidence in using the extended 3-D codes (TAN-RD and TAF-RD) to perform the final design calculations for the transportation of RD fuel under normal and hypothetical fire accident conditions.

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LIST OF SYMBOLS

Subscripts

i, j, k	denotes conditions at a grid point
f	denotes fluid properties
e	denotes effective properties

Superscripts

n	denotes conditions at a time step

Variables

a	thermal diffusivity, m^2/s
c	specific heat, $J/(kg \cdot °C)$
g	acceleration of gravity, m/s^2
h_H	heat transfer coefficient for horizontal surface, $W/(m^2 \cdot °C)$
h_V	heat transfer coefficient for vertical surface, $W/(m^2 \cdot °C)$
P	pressure, (kPa)a
P_W	partial pressure of water vapour, (kPa)a
$\dot{q}_H$	insolation for horizontal surface, W/m^2
$\dot{q}_S$	heat flux to cask outer surface, W/m^2
$\dot{q}_V$	insolation for vertical surface, W/m^2
$\dot{q}_W$	heat flux to cask inner surface, W/m^2
$\dot{Q}_G$	heat generation, W/m^3
$\dot{Q}_R$	radiant heat exchange within fuel region, W/m^3
t	time, s
T	temperature field, °C

Variables cont'd

T_A	ambient temperature, °C
T_{AC}	average temperature of neighbouring finite difference cells, °C
T_{AF}	average fuel temperature, °C
T_{AFS}	average fuel surface temperature
T_{CF}	average water temperature, °C
T_{FL}	flame temperature, °C
T_{IL}	inside lid temperature (at centre), °C
T_{MD}	maximum drain seal temperature, °C
T_{MF}	maximum fuel sheath temperature, °C
T_{ML}	maximum lid seal temperature, °C
T_{MT}	maximum trunnion temperature, °C
T_{MV}	maximum vent seal temperature, °C
T_{MW}	maximum cask wall temperatures, °C
T_{OL}	outside lid temperature (at centre), °C
T_{MS}	maximum cask outer surface temperature, °C
T_r	reference temperature, °C
T_S	cask outer surface temperature, °C
T_W	cask inner surface temperature, °C
x, y, z	coordinate system, m
$\vec{V}$	velocity field, m/s

Greek Symbols

α	cask outer surface absorptivity
β	coefficient of volume expansion, 1/°C

LIST OF SYMBOLS cont'd

Greek Symbols cont'd

ΔS	surface area for radiation of a finite difference cell, m^2
Δt	time step, s
ΔV	volume of a finite difference cell, m^3
ε_F	fuel region emissivity
ε_{FL}	flame emissivity
ε_E	cask outer surface emissivity
ε_I	cask inner surface emissivity
λ	thermal conductivity, $W/(m \cdot °C)$
ν	kinematic viscosity, m^2/s
ρ	density, kg/m^3
σ	Stefan-Boltzmann constant, $W/(m^2 \cdot °K^4)$

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To Mr. H.N. Isaac
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THERMAL ANALYSIS OF AN IRRADIATED FUEL ROAD CASK FOR RECENTLY DISCHARGED FUEL UNDER NORMAL AND FIRE ACCIDENT CONDITIONS

1.0 INTRODUCTION

An existing special purpose 3-D heat transfer code, originally developed for the thermal analysis of the road cask for 10 year cooled fuel (Reference Case/1/) has been extended to carry out the analysis for the Recently Discharged (RD) fuel. The code provides in addition to the velocity field within the cavity, the temperature distribution throughout the entire cask. This data is required for evaluating the performance of the cask for transporting RD fuel under normal and fire accident conditions as specified in the Regulations/2/.

The main objectives of this report are to describe the following:

i) Extension of the 3-D heat transfer code
ii) Verification of the code using existing experimental results/3/.

As in the Reference Case, there are two versions of the code. They are called TAN-RD and TAF-RD.

TAN-RD is used for analyzing the road cask for RD fuel under normal operating conditions. This basically involves calculating cask temperatures taking into account the internal heat generation and ambient conditions, with and without insolation. TAN-RD consists of a main program and 23 subroutines (see Appendix A).

TAF-RD is used for analyzing the road cask under regulatory fire accident conditions. It consists of modelling the temperature response of the cask to half an hour radiative and convective environment at high temperature (800°C). TAF-RD differs from TAN-RD only with respect to the heat input. Consequently TAF-RD consists of a main program and the 23 subroutines of TAN-RD, one of which has been modified so as to simulate the entire cask in an engulfing fire (see Appendix B).

In addition the application of the code is demonstrated through the analysis of the road cask for RD under normal and fire accident conditions. The final

design calculations which will assist Nuclear Materials Management Department to produce a safety analysis report for AECB licensing purposes will be presented in other reports.

2.0 EXTENSION OF THE 3-D HEAT TRANSFER CODE

Figure 1 shows 1/4 of the irradiated fuel road cask. The cask is of rectangular geometry with a cavity accommodating one aluminum fuel basket surrounded on the sides by a steel liner. Up to 18 fuel bundles can be stored in the aluminum basket. The aluminum basket and steel liner are shown in Figure 2. The cask material is 304L stainless steel. An impact limiter made of redwood encased in stainless steel sheet is placed over the top to protect the cask lid during impact.

The heat generated within the cask cavity is transferred to the cask inner surfaces by natural convection, conduction and radiation which is then conducted through the cask walls. The heat loss from the cask outer surface or the heat gained from the environment is by natural convection and radiation. In extending the analytical tools of Reference/1/ to perform the thermal analysis for RD fuel the following assumptions have been made:

2.1 Assumptions

Cask Wall

i) Thermal properties are independent of temperature.

ii) Before and after the fire the cask is considered to be in a black environment (thermal radiation emitted from the cask outer surface is absorbed by the surrounding).

iii) Heat transfer through the impact limiter is negligible.

Cask Cavity

i) Flow is incompressible and laminar.

ii) Thermal properties are independent of temperature (except density changes).

iii) Fuel region is represented by a medium with equivalent thermal properties based on the experimental results of Reference/3/.

It should be noted that over the temperature range encountered the thermal properties do not change appreciably.

2.2 Governing Equations

Based on the above assumptions the equations governing the heat flow throughout the cask are as follow:

Cask Wall

The heat transfer through the cask wall is given by:

$$\rho c \frac{\partial T}{\partial t} = \lambda \nabla^2 T \qquad (2\text{-}1)$$

Cask Cavity

The cask cavity is modelled by separating it into two regions, a fluid region and a fuel region. The fluid region consists of the cavity fluid that transfers heat by convection from the fuel region to the cask wall. The fuel region is modelled as a solid medium with equivalent thermal properties to account for the convection effects within the steel liner/aluminum basket assembly. The effects of the radiant heat exchange between the fuel region and the cask inner walls as well as the radiant heat exchange within the aluminum basket holes were also modelled. A layer of vapour with traces of air will exist between the top of the aluminum basket and the cask lid. The effects of this layer on the fuel temperature and internal cask pressure will be negligible. The air/vapour layer effects were accounted for through the use of the equivalent thermal properties. Therefore the remainder of the cavity was modelled as water.

a) Fluid Region

The equations governing the fluid region are:

$$\nabla \cdot \vec{V} = 0 \qquad (2\text{-}2)$$

$$\frac{D\vec{V}}{Dt} = -\frac{1}{\rho} \nabla P - \vec{g}\beta (T - T_r) + \nu \nabla^2 \vec{V} \qquad (2\text{-}3)$$

$$\rho c \frac{DT}{Dt} = \lambda \nabla^2 T \qquad (2\text{-}4)$$

b) Fuel Region

The equations governing the fuel region are:

$$(\rho c)_e \frac{\partial T}{\partial t} = \lambda_e \nabla^2 T + \dot{Q}_G - \dot{Q}_R \qquad (2\text{-}5)$$

where:

$$\dot{Q}_R = \sigma \, \varepsilon_F \, \frac{\Delta S}{\Delta V} \, (T^4 - T_{AC}^4)$$

The above equations have been numerically solved using the finite difference method. The finite difference approximations to these equations and the solution procedure have been described elsewhere/1,4,5,6,7/.

For a cavity containing water and water vapour the internal pressure is obtained from steam tables at a saturation temperature equal to the average temperature of the hottest bundle, T_{HB}.

The 3-D finite heat transfer code of Reference/1/ has been extended to account for the RD fuel region configuration (steel liner/aluminum basket). The two versions of the code TAN-RD and TAF-RD provide average temperatures for the bundles within the aluminum basket holes but do not explicitly give the fuel sheath temperature. As described in Reference/1/ the maximum fuel sheath temperature was determined from previous experimental results.

3.0 VERIFICATION OF THE 3-D HEAT TRANSFER CODE

The verification of the extended version of the code has been carried out for the cavity model only. This involves testing the adequacy of the code to predict the temperature distribution within the cask cavity. This verifies both TAN-RD and TAF-RD for the cask cavity. The verification of the code for the heat input from the fire to the cask surface and also for the conduction through the wall has been previously accomplished/1/. Therefore only the verification of the heat transfer model for the cask cavity is described below.

The theoretical cavity model was verified using full scale experimental test results/3/ for the case of Water Cavity with an impact limiter. The effect of the impact limiter is to provide thermal insulation. Figure 3 shows a schematic diagram of the experimental cask and Figure 4 shows the dimensions for the theoretical model of the cavity. Table 1 lists the thermal properties of the fluid and fuel region used in the analysis. The following initial and boundary conditions were applied:

Initial Conditions

$$\text{at } t=0;\ \vec{V}=0;\ P=1;\ T=T_A \qquad (3\text{-}1)$$

Boundary Conditions

$$\vec{V}=0;\ T=T_W \text{ (see Figures 5 \& 6 and Table 2)} \qquad (3\text{-}2)$$

Using the extended version of the code for RD fuel and with the experimental wall temperatures as imposed boundary conditions, temperature distributions within the cask cavity containing water have been obtained for various heat inputs. Figure 7 compares the theoretical average temperature of the hottest bundle with the experimental results of reference /3/ for 16 bundles and with the impact limiter in place. As this figure illustrates the theoretical predictions are in good agreement with the experimental results.

4.0 APPLICATION OF THE 3-D HEAT TRANSFER CODE

The main purpose of this section is to demonstrate the application of the code to a road cask for RD fuel under normal and fire accident conditions. The final design calculations for licensing purposes will be presented in other reports.

4.1 Thermal Analysis-Normal (TAN-RD)

To determine the maximum cask wall and fuel temperatures for a steel liner/ aluminum basket road cask during normal operation, the following initial and boundary conditions have been applied:

Initial Conditions

$$\text{at } t=o;\ \vec{V}=0;\ P=1;\ T=T_A \tag{4-1}$$

Boundary Conditions

i) Cask Outer Surface

This boundary condition includes the heat loss by convection and radiation and also the insolation gain.

$$\dot{q}_S = \begin{cases} h_H\,(T_A - T_S) + \sigma\,\varepsilon_E\,(T_A^4 - T_S^4) + \dot{q}_H & \text{for horizontal surfaces} \\ h_V\,(T_A - T_S) + \sigma\,\varepsilon_E\,(T_A^4 - T_S^4) + \dot{q}_V & \text{for vertical surfaces} \end{cases} \tag{4-2}$$

Where h_H and h_V are evaluated from correlations of natural convection/1/.

ii) Cask Inner Surface

$$\vec{V}_W = 0$$

$$\dot{q}_W = \lambda_f \frac{\partial T}{\partial n} + \sigma\,\varepsilon_I\,(T^4_{AFS} - T^4_W) \tag{4-3}$$

where:

$\frac{\partial T}{\partial n}$ = temperature gradient normal to the surface

subscript f denotes fluid conditions

Incorporating the above initial and boundary conditions into the 3-D code the version TAN-RD (Thermal Analysis Normal for RD fuel) was created. A listing of this version is given in Appendix A. This code computes the natural convection including the heat conduction through the fuel region and radiant heat exchange within the cavity. It further computes the heat conduction through the wall by accounting for the heat loss (by natural convection and radiation) and the insolation gain (solar heating). The required data for this analysis are presented in Figure 8 and Tables 3, 4, and 5.

The main results obtained at locations of interest are summarized in Table 6. These results correspond to zero insolation gain and also to insolation gain for 12 hours.

4.2 Thermal Analysis-Fire (TAF-RD)

The thermal response of the steel liner/aluminum basket road cask to an engulfing fire of 0.5 hour duration was carried out by applying the following initial and boundary conditions to the governing conditions.

Initial Conditions

at t=0; $\vec{V}$, P and T results from normal analysis with insolation gain. (4-4)

Boundary Conditions

i) Cask Outer Surface

Assuming that during the fire the heat input to the cask outer surface is by natural convection and radiation, the following boundary conditions apply:

During the fire:

$$\dot{q}_S = \begin{cases} h_H (T_{FL} - T_S) + \sigma \varepsilon (T_{FL}^4 - T_S^4) & \text{for horizontal surfaces} \\ h_V (T_{FL} - T_S) + \sigma \varepsilon (T_{FL}^4 - T_S^4) & \text{for vertical surfaces} \end{cases} \quad (4\text{-}5)$$

where:

$$\varepsilon = (1/\varepsilon_{FL} + 1/\alpha - 1)^{-1}$$

After the fire the boundary conditions given below apply. It includes the

heat loss by natural convection and radiation as well as the insolation gain.

After the fire:

$$\dot{q}_S = \begin{cases} h_H (T_A - T_S) + \sigma \varepsilon_E (T_A^4 - T_S^4) + \dot{q}_H & \text{for horizontal surfaces} \\ h_V (T_A - T_S) + \sigma \varepsilon_E (T_A^4 - T_S^4) + \dot{q}_V & \text{for vertical surfaces} \end{cases} \quad (4\text{-}6)$$

In the post fire analysis, the heat loss from the bottom of the cask was ignored.

ii) Inner Cask Surface

$$\vec{V}_W = 0$$

$$\dot{q}_W = \lambda_f \frac{\partial T}{\partial n} + \sigma \varepsilon_I (T^4_{AFS} - T^4_W) \quad (4\text{-}7)$$

where:

$\frac{\partial T}{\partial n}$ = temperature gradient normal to the surface

subscript f denotes fluid conditions.

The analysis was carried out based on the information given in Figure 9 and Tables 7, 8 and 9. The computer version used was the version TAF-RD (Thermal Analysis Fire for RD fuel) given in Appendix B. This is the same version as the version TAN-RD except it includes the heat input from the fire to all cask surfaces exposed to fire. The post fire analysis was performed using the version TAN-RD with initial conditions from the results of the 0.5 hour fire analysis.

Figure 10 shows the fire accident analysis results at several cask locations as a function of time and Table 10 summarizes the maximum temperatures attained under fire accident conditions.

5.0 CONCLUSIONS

a) A comparison of the predicted fuel temperatures with experimental temperature results as a function of the heat input level shows that the heat transfer model for the fuel cavity with equivalent thermal properties is adequate.

b) The representative results obtained for a steel liner/aluminum basket cask for RD fuel under normal and fire accident conditions demonstrate the capability of both versions (TAN-RD and TAF-RD) of the 3-D heat transfer code.

c) The code developed here can be applied with confidence to perform the final design heat transfer calculations of a road cask for the transportation of RD fuel.

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APPENDIX A

COMPUTER CODE TAN-RD

This Appendix gives a listing of the computer program TAN-RD (Thermal Analysis Normal for RD fuel) which was used to carry out the thermal analysis of a road cask for RD fuel under normal operating conditions. It consists of a main program and 23 subroutines.

```
COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
COMMON /BL2/ R,B,VK,THD,CP
COMMON /BL3/ CR,ETD
COMMON /BL4/ DT
COMMON /BL5/ T1,T2,T3,T4,T5,T6
COMMON /BL6/ M,N,L
COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
COMMON /BL8/ TR,G
COMMON /BL9/ ND
COMMON /BL10/ I,J,K
COMMON /BL11/ A11,A12,A13,X33,XM323,XP323
COMMON /BL12/ A11M,A12M,A13M,X33M,XM323M,XP323M
COMMON /BL21/ B11,B12,B13,Y33,YM323,YP323
COMMON /BL22/ B11N,B12N,B13N,Y33N,YM323N,YP323N
COMMON /BL31/ C11,C12,C13,Z33,ZM323,ZP323
COMMON /BL32/ C11L,C12L,C13L,Z33L,ZM323L,ZP323L
COMMON /BL51/ FKU,FKV,FKW
COMMON /BL52/ SPD
COMMON /BL53/ TDIA
COMMON /BL54/ RD1,RD2,RD3,RD4
COMMON /BL55/ CST1,CST2,CST3,CST4
COMMON /BL56/ EX2,EX3,EX4
COMMON /BL57/ UC,VC,WC
COMMON /BL58/ IS,IE,JS,JE,KS,KE
COMMON /BL59/ TOL,CRT,ITM,NGP,ITER
COMMON /BL60/ IFU,IFV,IFW,IFT
COMMON /BL61/ EPR
COMMON /BL72/ DXP,DYP,DZP
COMMON /BL83/ SIG,TABS
COMMON /BL84/ ESFR
COMMON /BL85/ M1,M2,N1,N2,K1,K2
COMMON /BL86/ TWR1,TWR4
COMMON /BL87/ TFR1,TFR4
COMMON /BL88/ EW,ESA
COMMON /BL91/ RL1,RL2,RL3,RL4,RL5
COMMON /BL92/ RU1,RU2,RU3,RU4,RU5
COMMON /BL93/ RYT,RYB,RYL
COMMON /BLS/ S1,S2,S3,S4,S5,S6
COMMON /PRTS/ RA,TKAB,VISS,VISH,BET,CPA,GRV
COMMON /CND1/ YZ,XZ,XY,YZDX,XZDY,XYDZ
COMMON /CND2/ TC1,TC2,TC3,TC4,TC5,TC6,TC7,TC8
COMMON /CND3/ E,TF,TA,QHI,QVI,HTP,HBP,HLP
COMMON /CND4/ TF1,TF2,TF3,TF4,TF5,TF6
COMMON /CND5/ IRF,ICF
COMMON /CND6/ MIL,NIL,LIL,ILD
COMMON /CND7/ IHS,IHF,KHS,KHF,LCT
COMMON /CND8/ IDA,KDA,NDAL
COMMON /CND9/ IO,MCI,NCI,LCI
COMMON /CND10/ IEIST
COMMON /EXP1/ DXC,DYC,DZC
COMMON /EXP2/ SP1,SP2,SP3,SP4,SP5,SP6
COMMON /EXP3/ CN1,CN2,CN3,CN4,CN5,CN6
DIMENSION A(4,9,16,8)
DIMENSION U(9,16,8),V(9,16,8),W(9,16,8),P(9,16,8),T(9,16,8)
DIMENSION Q(9,16,8),NCP(9,16,8),DFDP(9,16,8)
DIMENSION UP(9,16),VP(9,16),TP(9,16)
DIMENSION QR(9,16,8)
DIMENSION NCR(9,16,8)
DIMENSION EIFR(9,16,8)
DIMENSION T1(25,25),T2(25,25),T3(25,25)
DIMENSION T4(25,25),T5(25,25),T6(25,25)
DIMENSION TF1(25,25),TF2(25,25),TF3(25,25)
DIMENSION TF4(25,25),TF5(25,25),TF6(25,25)
DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
DIMENSION XX(50),YY(50),ZZ(50)
DIMENSION DFDP1(50),DFDP2(50),DFDP3(50)
```

```
      DIMENSION DXP(50),DYP(50),DZP(50)
      DIMENSION C(2,11,21,10)
      DIMENSION NCC(11,21,10)
      DIMENSION NFL(11,21,10)
C
C     DATA FOR RADIATIVE HEAT TRANSFER
C
      DATA IRF/1/
      DATA EB,ESFR/2*0.7/
C
C     DATA FOR CONVECTIVE HEAT TRANSFER
C
      DATA (DX(I),I=1,9)/9*0.095/
      DATA (DY(J),J=1,16)/16*0.09/
      DATA (DZ(K),K=1,8)/8*0.088/
      DATA M,N,L/9,16,8/
      DATA M1,M2,N1,N2,K1,K2/2,8,2,13,2,7/
      DATA II1,II2,JJ1,JJ2,KK1,KK2/4,8,4,7,6,7/
      DATA IR1,IR2,JR1,JR2,KR1,KR2/4,8,4,7,6,7/
      DATA R,CP,TK,VK,B,THD/962.2,4186.8,120.0,3.168E-7,7.2E-4,1.69E-7/
      DATA RS,CPS,TKS/5312.0,676.9,120.0/
      DATA TR/38.0/
      DATA CST1,CST2,CST3,CST4/9.0E-4,1.3022E-3,8.5467E-3,34.93E-3/
      DATA EX2,EX3,EX4/0.1605,0.62,0.8858/
      DATA SCFX,SCFY/2*1.45/
      DATA IBC/1/
      DATA DT/1.0/
      DATA ND/3/
      DATA QU/99910.79/
      DATA EPR/0.059/
      DATA NS,NTS/199,50/
      DATA NCOUNT,NW/0,1/
      DATA ITM/100/
      DATA TOL/1.0E-4/
      DATA SPD/1.7/
      DATA G/9.81/
      DATA TDIA/0.1/
      DATA RD1,RD2,RD3,RD4/1.0E1,6.0E1,2.0E2,1.0E4/
      DATA UC,VC,WC/3*0.0/
      DATA NPF,NPM/1,2/
      DATA NRED/1/
      DATA NCAV/1/
      DATA NWAL/1/
      DATA NHO/5/
      DATA TCAVI/150.0/
      DATA MSL,NSL,LSL/3,10,3/
C
C     DATA FOR HEAT CONDUCTION
C
      DATA SIG,TABS/5.669E-8,273.0/
      DATA MC,NC,LC/11,21,10/
      DATA MCI,NCI,LCI/11,18,10/
      DATA IO/4/
      DATA DXC,DYC,DZC/0.095,0.09,0.088/
      DATA TKC,RC,CPC/17.0,7817.0,460.0/
      DATA TKF/120.0/
      DATA DTC/50.0/
      DATA NSC,NTC/3,288/
      DATA ESA,EW/2*0.5/
      DATA TF/800.0/
      DATA TA,QHI,QVI/38.0,800.0,200.0/
      DATA ICF/1/
      DATA MIL,NIL,LIL,ILD/11,18,10,2/
      DATA IHS,IHF,KHS,KHF,LCT/4*5,7/
      DATA NDAL/0/
      DATA IDA,KDA/2,2/
```

```
      DATA STP,SBP,SLP/1.145,1.9,1.53/
      DATA SP1,SP2,SP3,SP4,SP5,SP6/10.37,0.0,0.0,1.97,10.37,0.0/
      DATA CN1,CN2,CN3,CN4,CN5,CN6/130.0,0.0,130.0,143.0,130.0,0.0/
      DATA TWALI/140.0/
      DATA IEIST/0/
C
      OPEN(5,FILE='IN.DAT',STATUS='OLD')
      OPEN(6,FILE='OUT.DAT',STATUS='NEW')
      OPEN(9,FILE='SAV.DAT',STATUS='NEW')
C
C     EVALUATION OF CONSTANTS FOR HEAT CONDUCTION
C
      MM1=M-1
      NM1=N-1
      LM1=L-1
      MM2=M-2
      NM2=N-2
      LM2=L-2
      X=DXC/2.0
      Y=DYC/2.0
      Z=DZC/2.0
      YZ=Y*Z
      XZ=X*Z
      XY=X*Y
      XYZ=X*Y*Z
      YZDX=YZ/DXC
      XZDY=XZ/DYC
      XYDZ=XY/DZC
      TC=RC*CPC*XYZ
      TC1=TC
      TC2=2.0*TC
      TC3=3.0*TC
      TC4=4.0*TC
      TC5=5.0*TC
      TC6=6.0*TC
      TC7=7.0*TC
      TC8=8.0*TC
      DO 91 K=1,LC
      DO 91 J=1,NC
      DO 91 I=1,MC
      C(1,I,J,K)=TWALI
   91 CONTINUE
C
C     EVALUATION OF CONSTANTS FOR CONVECTION
C
      CF=R*CP
      CS=RS*CPS
      ETK=EPR*TK+(1.0-EPR)*TKS
      EHC=EPR*CF+(1.0-EPR)*CS
      ETD=ETK/EHC
      CR=CF/EHC
      XL=0.0
      YL=0.0
      DO 1 I=2,MM1
      DXP(I)=DX(I)/SCFX
      XL=XL+DXP(I)
    1 CONTINUE
      DO 2 J=2,NM1
      DYP(J)=DY(J)/SCFY
      YL=YL+DYP(J)
    2 CONTINUE
      DO 4 I=2,MM1
      DXFA(I-1)=(DX(I-1)+DX(I))/2.0
      DXFA(I)=(DX(I)+DX(I+1))/2.0
      IF(I.EQ.2) XX(I-1)=-DX(I-1)/2.0
      XX(I)=XX(I-1)+DXFA(I-1)
```

```
      DFDP1(I)=(1.0/DXFA(I-1)+1.0/DXFA(I))/DX(I)
    4 CONTINUE
      DO 5 J=2,NM1
      DYFA(J-1)=(DY(J-1)+DY(J))/2.0
      DYFA(J)=(DY(J)+DY(J+1))/2.0
      IF(J.EQ.2) YY(J-1)=-DY(J-1)/2.0
      YY(J)=YY(J-1)+DYFA(J-1)
      DFDP2(J)=(1.0/DYFA(J-1)+1.0/DYFA(J))/DY(J)
    5 CONTINUE
      DO 6 K=2,LM1
      DZFA(K-1)=(DZ(K-1)+DZ(K))/2.0
      DZFA(K)=(DZ(K)+DZ(K+1))/2.0
      IF(K.EQ.2) ZZ(K-1)=-DZ(K-1)/2.0
      ZZ(K)=ZZ(K-1)+DZFA(K-1)
      DFDP3(K)=(1.0/DZFA(K-1)+1.0/DZFA(K))/DZ(K)
    6 CONTINUE
      NGP=MM2*NM2*LM2
      GRF=0.0
      PRL=VK/THD
      RAH=GRF*PRL
      IF(IBC.EQ.1) CALL TCS1
      IF(IBC.EQ.2) CALL TCS2
C
C     INITIALIZATION OF VARIABLES
C
      DO 10 K=1,L
      DO 10 J=1,N
      DO 10 I=1,M
      U(I,J,K)=0.0
      V(I,J,K)=0.0
      W(I,J,K)=0.0
      T(I,J,K)=TCAVI
      P(I,J,K)=1.0
      QR(I,J,K)=0.0
      Q(I,J,K)=0.0
      NCP(I,J,K)=NPF
      EIFR(I,J,K)=0.0
   10 CONTINUE
      DO 15 K=K1,K2
      DO 15 J=N1,N2
      DO 15 I=M1,M2
      NCP(I,J,K)=NPM
   15 CONTINUE
      DO 18 K=KK1,KK2
      DO 18 J=JJ1,JJ2
      DO 18 I=II1,II2
      Q(I,J,K)=QU/EHC
      IF(NHO.EQ.5) Q(I,5,7)=Q(I,5,7)/4.0
      IF(NHO.EQ.5) Q(I,6,7)=Q(I,6,7)/4.0
      WRITE(6,*) QU,EHC,Q(I,J,K)
   18 CONTINUE
      DO 19 K=KR1,KR2
      DO 19 J=JR1,JR2
      DO 19 I=IR1,IR2
      EIFR(I,J,K)=EB
   19 CONTINUE
      DO 42 K=1,L
      WRITE(6,31)
   31 FORMAT(/)
      DO 42 I=1,M
      WRITE(6,41) (NCP(I,J,K),J=1,N)
   41 FORMAT(25I5)
   42 CONTINUE
      CALL NCRAD(NCR)
C
C     SOLUTION OF HEAT CONDUCTION
```

```
C
      TIME=0.0
      TIMC=0.0
      IF(NRED.GT.0) CALL READ(TIMC,TIME,C,U,V,W,T,P,A,MC,NC,LC)
      CALL NLCS(NCC,NFL,MC,NC,LC)
      NCNT=0
      NWC=1
      IF(NWAL.EQ.0) GO TO 125
   32 CONTINUE
      IEIST=IEIST+1
      TSG=(C(1,1,1,1)+C(1,1,21,1)+C(1,1,1,10)+C(1,1,21,10))/4.0
      CALL CVR(TA,TSG,STP,SBP,SLP,HTP,HBP,HLP)
      CALL FLT(A,MCI,NCI,LCI,IO)
      IF(IRF.GT.0) CALL TAVF(A)
      TIMC=TIMC+DTC
      E=0.0
      CALL COND(DTC,TKC,TKF,MC,NC,LC,C,NCC,NFL)
      NCNT=NCNT+1
      IF(NCNT.NE.NWC) GO TO 120
      NWC=NWC+NSC
      IF(NCNT.EQ.1) NSC=NSC+1
      WRITE(6,172)
  172 FORMAT('1')
      WRITE(6,112) TIMC
  112 FORMAT( ' TIME=',E15.4)
      DO 118 K=1,LC
      WRITE(6,115)
  115 FORMAT(/)
      DO 118 J=1,NC
      JT=NC+1-J
      WRITE(6,116) (C(1,I,JT,K),I=1,MC)
  116 FORMAT(11E11.4)
  118 CONTINUE
      IF(RYT.LT.RL1.OR.RYT.GT.RU2) WRITE(6,81) RL1,RYT,RU2
      IF(RYB.LT.RL3.OR.RYB.GT.RU3) WRITE(6,82) RL3,RYB,RU3
      IF(RYL.LT.RL4.OR.RYL.GT.RU5) WRITE(6,83) RL4,RYL,RU5
   81 FORMAT(' RL1=',E12.5,2X,'RYT=',E12.5,2X,'RU2=',E12.5)
   82 FORMAT(' RL3=',E12.5,2X,'RYB=',E12.5,2X,'RU3=',E12.5)
   83 FORMAT(' RL4=',E12.5,2X,'RYL=',E12.5,2X,'RU5=',E12.5)
      WRITE(6,92) HTP,HBP,HLP
   92 FORMAT(' HTP=',E12.5,2X,'HBP=',E12.5,2X,'HLP=',E12.5)
      CALL WRITE(TIMC,TIME,C,U,V,W,T,P,MC,NC,LC)
  120 CONTINUE
  125 CONTINUE
C
C     INCREMENT OF TIME
C
      NECT=0
      IF(NCAV.EQ.0) GO TO 61
   11 CONTINUE
      NECT=NECT+1
      TIME=TIME+DT
C
C     CALCULATION OF VELOCITY FIELD
C
      DO 7 K=2,LM1
      DO 7 J=2,NM1
      DO 7 I=2,MM1
      CALL PMS(U,V,W)
      IFU=NCP(I,J,K)
      IFV=NCP(I,J,K)
      IFW=NCP(I,J,K)
      IF(I.LT.MM1) CALL US(A,U,V,W,P)
      IF(J.LT.NM1) CALL VS(A,U,V,W,P,T)
      IF(K.LT.LM1) CALL WS(A,U,V,W,P)
    7 CONTINUE
```

```
      CALL VBC(A)
C
C     CALCULATION OF PRESSURE FIELD
C
      DO 8 K=2,LM1
      DO 8 I=2,MM1
      DO 8 J=2,NM1
      DFDP(I,J,K)=DT*(DFDP1(I)+DFDP2(J)+DFDP3(K))
    8 CONTINUE
      CALL PS(A,P,DFDP)
      CALL VBC(A)
C
C     CALCULATION OF TEMPERATURE FIELD
C
      IF(IRF.GT.0) CALL TAVW(C,IO,MC,NC,LC,MCI,NCI,LCI)
      IF(IRF.GT.0) CALL RAD(NCR,T,QR,EHC,EIFR)
      DO 34 K=K1,K2
      DO 34 J=N1,N2
      DO 34 I=M1,M2
      IF(J.GT.NSL.AND.K.LE.LSL) GO TO 33
      IF(J.GT.NSL.AND.I.LE.MSL) GO TO 33
      U(I,J,K)=0.0
      V(I,J,K)=0.0
      W(I,J,K)=0.0
      A(1,I,J,K)=0.0
      A(2,I,J,K)=0.0
      A(3,I,J,K)=0.0
   33 CONTINUE
   34 CONTINUE
      DO 35 K=2,LM1
      DO 35 J=2,NM1
      DO 35 I=2,MM1
      IFT=NCP(I,J,K)
      CALL TS(A,U,V,W,T,Q,QR)
   35 CONTINUE
      CALL ET(C,IO,MC,NC,LC,MCI,NCI,LCI)
      IF(IBC.EQ.1) CALL TBC1(A)
C     IF(IBC.EQ.2) CALL TBC2(A)
C
C     UPDATING OF VARIABLES
C
      DO 50 K=1,L
      DO 50 J=1,N
      DO 50 I=1,M
      U(I,J,K)=A(1,I,J,K)
      V(I,J,K)=A(2,I,J,K)
      W(I,J,K)=A(3,I,J,K)
      T(I,J,K)=A(4,I,J,K)
   50 CONTINUE
C
C     OUTPUT OF RESULTS
C
   59 CONTINUE
      TBFS=0.0
      NCOUNT=NCOUNT+1
      IF(NCOUNT.NE.NW) GO TO 60
      NW=NW+NS
      IF(NCOUNT.EQ.1) NS=NS+1
      WRITE(6,72)
   72 FORMAT('1')
      WRITE(6,12) TIME
   12 FORMAT(' TIME=',E15.7)
      WRITE(6,71) NCOUNT,ITER,TOL,CRT
   71 FORMAT(' NCOUNT=',I10,' ITER=',I10,' TOL=',E15.5,' CRT=',E15.5)
      WRITE(6,56) GRF,PRL,RAH
   56 FORMAT(' GRF=',E15.5,' PRL=',E15.5,' RAH=',E15.5)
```

```
      DO 55 K=2,LM1
      WRITE(6,51)
   51 FORMAT(/)
      WRITE(6,52) ZZ(K)
   52 FORMAT(' RESULTS AT PLANE Z=',E15.4,' ')
      JM=0
      DO 55 J=2,NM1
      JM=JM+1
      WRITE(6,53) YY(J)
   53 FORMAT(' Y=',E15.4)
      IM=0
      DO 55 I=2,MM1
      IM=IM+1
      IF(ND.GE.1) UAV=0.5*(A(1,I,J,K)+A(1,I-1,J,K))
      IF(ND.GE.2) VAV=0.5*(A(2,I,J,K)+A(2,I,J-1,K))
      IF(ND.GE.3) WAV=0.5*(A(3,I,J,K)+A(3,I,J,K-1))
      UP(IM,JM)=UAV
      VP(IM,JM)=VAV
      TP(IM,JM)=A(4,I,J,K)
      WRITE(6,54)
     'I,J,K,XX(I),UAV,VAV,WAV,A(4,I,J,K),P(I,J,K),Q(I,J,K),QR(I,J,K)
   54 FORMAT(3I5,8E14.5)
      TBFS=TBFS+A(4,I,J,K)
   55 CONTINUE
      TBF=TBFS/FLOAT(NGP)
      WRITE(6,58) TBF
   58 FORMAT(' TBF=',E15.5)
   60 CONTINUE
      IF(NECT.LT.NTS) GO TO 11
   61 CONTINUE
      IF(NCNT.LT.NTC) GO TO 32
C     CALL WRITE(TIMC,TIME,C,U,V,W,T,P,MC,NC,LC)
      STOP
      END
```

```
      SUBROUTINE TCS1
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BLS/ S1,S2,S3,S4,S5,S6
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      S1=DX(1)/DX(2)
      S2=DX(M)/DX(MM1)
      S3=DY(1)/DY(2)
      S4=DY(N)/DY(NM1)
      S5=DZ(1)/DZ(2)
      S6=DZ(L)/DZ(LM1)
      RETURN
      END
```

```
      SUBROUTINE TCS2
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL11/ A11,A12,A13,X33,XM323,XP323
      COMMON /BL12/ A11M,A12M,A13M,X33M,XM323M,XP323M
      COMMON /BL21/ B11,B12,B13,Y33,YM323,YP323
      COMMON /BL22/ B11N,B12N,B13N,Y33N,YM323N,YP323N
      COMMON /BL31/ C11,C12,C13,Z33,ZM323,ZP323
      COMMON /BL32/ C11L,C12L,C13L,Z33L,ZM323L,ZP323L
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      X1=DX(1)/2.0
      X2=DXFA(1)
      X3=DXFA(2)+X2
      X11=X1**2
      X33=X3**2
      XM23=X2-X3
      XM123=X1/XM23
      XM323=X3/XM23
      XP23=X2+X3
      XP323=X3*XP23
      XP123=X1*XP23
      A1=X11-XP123-X33+XP323
      A11=1.0/A1
      A12=XM123/A1
      A13=XM323/A1
      X1M=DX(M)/2.0
      X2M=DXFA(M-1)
      X3M=DXFA(M-2)+X2M
      X11M=X1M**2
      X33M=X3M**2
      XM23M=X2M-X3M
      XM123M=X1M/XM23M
      XM323M=X3M/XM23M
      XP23M=X2M+X3M
      XP323M=X3M*XP23M
      XP123M=X1M*XP23M
      A1M=X11M-XP123M-X33M+XP323M
      A11M=1.0/A1M
      A12M=XM123M/A1M
      A13M=XM323M/A1M
      Y1=DY(1)/2.0
      Y2=DYFA(1)
      Y3=DYFA(2)+Y2
      Y11=Y1**2
      Y33=Y3**2
      YM23=Y2-Y3
      YM123=Y1/YM23
      YM323=Y3/YM23
      YP23=Y2+Y3
      YP323=Y3*YP23
      YP123=Y1*YP23
      B1=Y11-YP123-Y33+YP323
      B11=1.0/B1
      B12=YM123/B1
      B13=YM323/B1
      Y1N=DY(N)/2.0
      Y2N=DYFA(N-1)
      Y3N=DYFA(N-2)+Y2N
      Y11N=Y1N**2
      Y33N=Y3N**2
      YM23N=Y2N-Y3N
      YM123N=Y1N/YM23N
      YM323N=Y3N/YM23N
      YP23N=Y2N+Y3N
      YP323N=Y3N*YP23N
```

```
      YP123N=Y1N*YP23N
      B1N=Y11N-YP123N-Y33N+YP323N
      B11N=1.0/B1N
      B12N=YM123N/B1N
      B13N=YM323N/B1N
      Z1=DZ(1)/2.0
      Z2=DZFA(1)
      Z3=DZFA(2)+Z2
      Z11=Z1**2
      Z33=Z3**2
      ZM23=Z2-Z3
      ZM123=Z1/ZM23
      ZM323=Z3/ZM23
      ZP23=Z2+Z3
      ZP323=Z3*ZP23
      ZP123=Z1*ZP23
      C1=Z11-ZP123-Z33+ZP323
      C11=1.0/C1
      C12=ZM123/C1
      C13=ZM323/C1
      Z1L=DZ(L)/2.0
      Z2L=DZFA(L-1)
      Z3L=DZFA(L-2)+Z2L
      Z11L=Z1L**2
      Z33L=Z3L**2
      ZM23L=Z2L-Z3L
      ZM123L=Z1L/ZM23L
      ZM323L=Z3L/ZM23L
      ZP23L=Z2L+Z3L
      ZP323L=Z3L*ZP23L
      ZP123L=Z1L*ZP23L
      C1L=Z11L-ZP123L-Z33L+ZP323L
      C11L=1.0/C1L
      C12L=ZM123L/C1L
      C13L=ZM323L/C1L
      RETURN
      END
```

```
      SUBROUTINE PMS(U,V,W)
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL51/ FKU,FKV,FKW
      COMMON /BL53/ TDIA
      COMMON /BL54/ RD1,RD2,RD3,RD4
      COMMON /BL55/ CST1,CST2,CST3,CST4
      COMMON /BL56/ EX2,EX3,EX4
      COMMON /BL57/ UC,VC,WC
      DIMENSION U(M,N,L),V(M,N,L),W(M,N,L)
      IF(ND.GT.0) UC=0.5*(U(I,J,K)+U(I-1,J,K))
      IF(ND.GT.1) VC=0.5*(V(I,J,K)+V(I,J-1,K))
      IF(ND.GT.2) WC=0.5*(W(I,J,K)+W(I,J,K-1))
      TVEL=SQRT(UC*UC+VC*VC+WC*WC)
      GO TO (83,82,81),ND
   81 CONTINUE
      RDW=(TVEL*TDIA)/VK
      IF(RDW.LE.RD1) FKW=CST1*TDIA**2
      IF(RDW.GT.RD1.AND.RDW.LE.RD2) FKW=CST2*RDW**(-EX2)*TDIA**2
      IF(RDW.GT.RD2.AND.RDW.LE.RD3) FKW=CST3*RDW**(-EX3)*TDIA**2
      IF(RDW.GT.RD3) FKW=CST4*RDW**(-EX4)*TDIA**2
   82 CONTINUE
      RDV=(TVEL*TDIA)/VK
      IF(RDV.LE.RD1) FKV=CST1*TDIA**2
      IF(RDV.GT.RD1.AND.RDV.LE.RD2) FKV=CST2*RDV**(-EX2)*TDIA**2
      IF(RDV.GT.RD2.AND.RDV.LE.RD3) FKV=CST3*RDV**(-EX3)*TDIA**2
      IF(RDV.GT.RD3) FKV=CST4*RDV**(-EX4)*TDIA**2
   83 CONTINUE
      RDU=(TVEL*TDIA)/VK
      IF(RDU.LE.RD1) FKU=CST1*TDIA**2
      IF(RDU.GT.RD1.AND.RDU.LE.RD2) FKU=CST2*RDU**(-EX2)*TDIA**2
      IF(RDU.GT.RD2.AND.RDU.LE.RD3) FKU=CST3*RDU**(-EX3)*TDIA**2
      IF(RDU.GT.RD3) FKU=CST4*RDU**(-EX4)*TDIA**2
      RETURN
      END
```

```
      SUBROUTINE US(A,U,V,W,P)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL4/ DT
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ TR,G
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL51/ FKU,FKV,FKW
      COMMON /BL60/ IFU,IFV,IFW,IFT
      COMMON /BL61/ EPR
      DIMENSION A(4,M,N,L),U(M,N,L),V(M,N,L),W(M,N,L),P(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      GO TO (3,2,1),ND
    1 CONTINUE
      WA=(DX(I)*(W(I,J,K-1)+W(I,J,K))+DX(I+1)*(W(I+1,J,K-1)+
     'W(I+1,J,K)))/(4*DXFA(I))
      FFUZ=(U(I,J,K+1)-U(I,J,K))/DZFA(K)
      BFUZ=(U(I,J,K)-U(I,J,K-1))/DZFA(K-1)
      WFUZ=(FFUZ*(WA-ABS(WA))/2)+(BFUZ*(WA+ABS(WA))/2)
      SUZ=2*(FFUZ-BFUZ)/(DZFA(K)+DZFA(K-1))
    2 CONTINUE
      VA=(DX(I)*(V(I,J,K)+V(I,J-1,K))+DX(I+1)*(V(I+1,J,K)+
     'V(I+1,J-1,K)))/(4*DXFA(I))
      FFUY=(U(I,J+1,K)-U(I,J,K))/DYFA(J)
      BFUY=(U(I,J,K)-U(I,J-1,K))/DYFA(J-1)
      VFUY=(FFUY*(VA-ABS(VA))/2)+(BFUY*(VA+ABS(VA))/2)
      SUY=2*(FFUY-BFUY)/(DYFA(J)+DYFA(J-1))
    3 CONTINUE
      UA=U(I,J,K)
      FFUX=(U(I+1,J,K)-U(I,J,K))/DX(I+1)
      BFUX=(U(I,J,K)-U(I-1,J,K))/DX(I)
      UFUX=(FFUX*(UA-ABS(UA))/2)+(BFUX*(UA+ABS(UA))/2)
      FPX=(P(I,J,K)-P(I+1,J,K))/DXFA(I)
      SUX=(FFUX-BFUX)/DXFA(I)
      GO TO (11,12),IFU
   11 CONTINUE
      A(1,I,J,K)=U(I,J,K)+DT*(FPX-UFUX-VFUY-WFUZ+
     'VK*(SUX+SUY+SUZ))
      GO TO 13
   12 CONTINUE
      A(1,I,J,K)=U(I,J,K)+DT*(FPX-UFUX-VFUY-WFUZ
     '-EPR*(VK/FKU)*UA)
   13 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VS(A,U,V,W,P,T)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL4/ DT
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ TR,G
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL51/ FKU,FKV,FKW
      COMMON /BL60/ IFU,IFV,IFW,IFT
      COMMON /BL61/ EPR
      DIMENSION A(4,M,N,L),U(M,N,L),V(M,N,L),W(M,N,L),P(M,N,L),T(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      GO TO(3,2,1),ND
    1 CONTINUE
      WA=(DY(J)*(W(I,J,K)+W(I,J,K-1))+DY(J+1)*(W(I,J+1,K)+
     'W(I,J+1,K-1)))/(4*DYFA(J))
      FFVZ=(V(I,J,K+1)-V(I,J,K))/DZFA(K)
      BFVZ=(V(I,J,K)-V(I,J,K-1))/DZFA(K-1)
      WFVZ=(FFVZ*(WA-ABS(WA))/2)+(BFVZ*(WA+ABS(WA))/2)
      SVZ=2*(FFVZ-BFVZ)/(DZFA(K-1)+DZFA(K))
    2 CONTINUE
      VA=V(I,J,K)
      FFVY=(V(I,J+1,K)-V(I,J,K))/DY(J+1)
      BFVY=(V(I,J,K)-V(I,J-1,K))/DY(J)
      VFVY=(FFVY*(VA-ABS(VA))/2)+(BFVY*(VA+ABS(VA))/2)
      FPY=(P(I,J,K)-P(I,J+1,K))/DYFA(J)
      RV1=DY(J+1)/(2*DYFA(J))
      RV2=DY(J)/(2*DYFA(J))
      BFY=G*B*(T(I,J+1,K)*RV1+T(I,J,K)*RV2-TR)
      SVY=(FFVY-BFVY)/DYFA(J)
    3 CONTINUE
      UA=(DY(J)*(U(I-1,J,K)+U(I,J,K))+DY(J+1)*(U(I-1,J+1,K)+
     'U(I,J+1,K)))/(4*DYFA(J))
      FFVX=(V(I+1,J,K)-V(I,J,K))/DXFA(I)
      BFVX=(V(I,J,K)-V(I-1,J,K))/DXFA(I-1)
      UFVX=(FFVX*(UA-ABS(UA))/2)+(BFVX*(UA+ABS(UA))/2)
      SVX=2*(FFVX-BFVX)/(DXFA(I-1)+DXFA(I))
      GO TO (11,12),IFV
   11 CONTINUE
      A(2,I,J,K)=V(I,J,K)+DT*(FPY-UFVX-VFVY-WFVZ+BFY+
     'VK*(SVX+SVY+SVZ))
      GO TO 13
   12 CONTINUE
      A(2,I,J,K)=V(I,J,K)+DT*(FPY-UFVX-VFVY-WFVZ+EPR*BFY
     '-EPR*(VK/FKV)*VA)
   13 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WS(A,U,V,W,P)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL4/ DT
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ TR,G
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL51/ FKU,FKV,FKW
      COMMON /BL60/ IFU,IFV,IFW,IFT
      COMMON /BL61/ EPR
      DIMENSION A(4,M,N,L),U(M,N,L),V(M,N,L),W(M,N,L),P(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      GO TO(3,2,1),ND
    1 CONTINUE
      WA=W(I,J,K)
      FFWZ=(W(I,J,K+1)-W(I,J,K))/DZ(K+1)
      BFWZ=(W(I,J,K)-W(I,J,K-1))/DZ(K)
      SWZ=(FFWZ-BFWZ)/DZFA(K)
      WFWZ=(FFWZ*(WA-ABS(WA))/2)+(BFWZ*(WA+ABS(WA))/2)
      FPZ=(P(I,J,K)-P(I,J,K+1))/DZFA(K)
    2 CONTINUE
      VA=(DZ(K)*(V(I,J-1,K)+V(I,J,K))+DZ(K+1)*V(I,J-1,K+1)+
     'V(I,J,K+1))/(4*DZFA(K))
      FFWY=(W(I,J+1,K)-W(I,J,K))/DYFA(J)
      BFWY=(W(I,J,K)-W(I,J-1,K))/DYFA(J-1)
      VFWY=(FFWY*(VA-ABS(VA))/2)+(BFWY*(VA+ABS(VA))/2)
      SWY=2*(FFWY-BFWY)/(DYFA(J-1)+DYFA(J))
    3 CONTINUE
      UA=(DZ(K)*(U(I-1,J,K)+U(I,J,K))+DZ(K+1)*(U(I-1,J,K+1)+
     'U(I,J,K+1)))/(4*DZFA(K))
      FFWX=(W(I+1,J,K)-W(I,J,K))/DXFA(I)
      BFWX=(W(I,J,K)-W(I-1,J,K))/DXFA(I-1)
      UFWX=(FFWX*(UA-ABS(UA))/2)+(BFWX*(UA+ABS(UA))/2)
      SWX=2*(FFWX-BFWX)/(DXFA(I-1)+DXFA(I))
      GO TO (11,12),IFW
   11 CONTINUE
      A(3,I,J,K)=W(I,J,K)+DT*(FPZ-UFWX-VFWY-WFWZ+
     'VK*(SWX+SWY+SWZ))
      GO TO 13
   12 CONTINUE
      A(3,I,J,K)=W(I,J,K)+DT*(FPZ-UFWX-VFWY-WFWZ
     '-EPR*(VK/FKW)*WA)
   13 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TS(A,U,V,W,T,Q,QR)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL3/ CR,ETD
      COMMON /BL4/ DT
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ TR,G
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL60/ IFU,IFV,IFW,IFT
      COMMON /BL61/ EPR
      DIMENSION A(4,M,N,L),U(M,N,L),V(M,N,L),W(M,N,L),T(M,N,L)
      DIMENSION Q(M,N,L)
      DIMENSION QR(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      GO TO(3,2,1),ND
    1 CONTINUE
      WA=(W(I,J,K)+W(I,J,K-1))/2
      FFTZ=(T(I,J,K+1)-T(I,J,K))/DZFA(K)
      BFTZ=(T(I,J,K)-T(I,J,K-1))/DZFA(K-1)
      WFTZ=(FFTZ*(WA-ABS(WA))/2)+(BFTZ*(WA+ABS(WA))/2)
      STZ=2*(FFTZ-BFTZ)/(DZFA(K-1)+DZFA(K))
    2 CONTINUE
      VA=(V(I,J,K)+V(I,J-1,K))/2
      FFTY=(T(I,J+1,K)-T(I,J,K))/ DYFA(J)
      BFTY=(T(I,J,K)-T(I,J-1,K))/DYFA(J-1)
      VFTY=(FFTY*(VA-ABS(VA))/2)+(BFTY*(VA+ABS(VA))/2)
      STY=2*(FFTY-BFTY)/(DYFA(J-1)+DYFA(J))
    3 CONTINUE
      UA=(U(I,J,K)+U(I-1,J,K))/2
      FFTX=(T(I+1,J,K)-T(I,J,K))/DXFA(I)
      BFTX=(T(I,J,K)-T(I-1,J,K))/DXFA(I-1)
      UFTX=(FFTX*(UA-ABS(UA))/2)+(BFTX*(UA+ABS(UA))/2)
      STX=2*(FFTX-BFTX)/(DXFA(I-1)+DXFA(I))
      GO TO (11,12),IFT
   11 CONTINUE
      A(4,I,J,K)=T(I,J,K)+DT*(Q(I,J,K)-UFTX-VFTY-WFTZ+
     'THD'(STX+STY+STZ))
      GO TO 13
   12 CONTINUE
      A(4,I,J,K)=T(I,J,K)+DT*(Q(I,J,K)-CR*(UFTX+VFTY+WFTZ)
     '+ETD*(STX+STY+STZ)-QR(I,J,K))
   13 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VBC(A)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      DIMENSION A(4,M,N,L)
      I=1
      DO 1 K=2,LM1
      DO 1 J=2,NM1
      A(1,I,J,K)=0.0
      A(2,I,J,K)=-A(2,I+1,J,K)
      A(3,I,J,K)=-A(3,I+1,J,K)
    1 CONTINUE
      I=M
      DO 2 K=2,LM1
      DO 2 J=2,NM1
      A(1,I-1,J,K)=0.0
      A(2,I,J,K)=A(2,I-1,J,K)
      A(3,I,J,K)=A(3,I-1,J,K)
    2 CONTINUE
      J=1
      DO 3 K=1,L
      DO 3 I=1,M
      A(1,I,J,K)=-A(1,I,J+1,K)
      A(2,I,J,K)=0.0
      A(3,I,J,K)=-A(3,I,J+1,K)
    3 CONTINUE
      J=N
      DO 4 K=1,L
      DO 4 I=1,M
      A(1,I,J,K)=-A(1,I,J-1,K)
      A(2,I,J-1,K)=0.0
      A(3,I,J,K)=-A(3,I,J-1,K)
    4 CONTINUE
      K=1
      DO 5 J=2,NM1
      DO 5 I=1,M
      A(1,I,J,K)=-A(1,I,J,K+1)
      A(2,I,J,K)=-A(2,I,J,K+1)
      A(3,I,J,K)=0.0
    5 CONTINUE
      K=L
      DO 6 J=2,NM1
      DO 6 I=1,M
      A(1,I,J,K)=A(1,I,J,K-1)
      A(2,I,J,K)=A(2,I,J,K-1)
      A(3,I,J,K-1)=0.0
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TBC1(A)
      COMMON /BL5/ T1,T2,T3,T4,T5,T6
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ S1,S2,S3,S4,S5,S6
      DIMENSION A(4,M,N,L)
      DIMENSION T1(25,25),T2(25,25),T3(25,25)
      DIMENSION T4(25,25),T5(25,25),T6(25,25)
      I=1
      DO 1 K=2,LM1
      DO 1 J=2,NM1
      A(4,I,J,K)=T1(J,K)-S1*(A(4,I+1,J,K)-T1(J,K))
    1 CONTINUE
      I=M
      DO 2 K=2,LM1
      DO 2 J=2,NM1
      A(4,I,J,K)=T2(J,K)-S2*(A(4,I-1,J,K)-T2(J,K))
      A(4,I,J,K)=A(4,I-1,J,K)
    2 CONTINUE
      J=1
      DO 3 K=1,L
      DO 3 I=1,M
      A(4,I,J,K)=T3(I,K)-S3*(A(4,I,J+1,K)-T3(I,K))
    3 CONTINUE
      J=N
      DO 4 K=1,L
      DO 4 I=1,M
      A(4,I,J,K)=T4(I,K)-S4*(A(4,I,J-1,K)-T4(I,K))
    4 CONTINUE
      K=1
      DO 5 J=2,NM1
      DO 5 I=1,M
      A(4,I,J,K)=T5(I,J)-S5*(A(4,I,J,K+1)-T5(I,J))
    5 CONTINUE
      K=L
      DO 6 J=2,NM1
      DO 6 I=1,M
      A(4,I,J,K)=T6(I,J)-S6*(A(4,I,J,K-1)-T6(I,J))
      A(4,I,J,K)=A(4,I,J,K-1)
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PS(A,P,DFDP)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL4/ DT
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL9/ ND
      COMMON /BL52/ SPD
      COMMON /BL58/ IS,IE,JS,JE,KS,KE
      COMMON /BL59/ TOL,CRT,ITM,NGP,ITER
      DIMENSION A(4,M,N,L)
      DIMENSION P(M,N,L)
      DIMENSION DFDP(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      K=1
      ITER=0
      D1=0.0
      D2=0.0
      D3=0.0
   16 CONTINUE
      ITER=ITER+1
      SUM=0.0
      DO 20 K=2,LM1
      DO 20 J=2,NM1
      DO 20 I=2,MM1
      KS=2
      KE=LM1
      JS=2
      JE=NM1
      IS=2
      IE=MM1
      IF(ND.GT.0) D1=(A(1,I,J,K)-A(1,I-1,J,K))/DX(I)
      IF(ND.GT.1) D2=(A(2,I,J,K)-A(2,I,J-1,K))/DY(J)
      IF(ND.GT.2) D3=(A(3,I,J,K)-A(3,I,J,K-1))/DZ(K)
      D=D1+D2+D3
      SUM=SUM+ABS(D)
      DP=SPD*(-D/DFDP(I,J,K))
      P(I,J,K)=P(I,J,K)+DP
      DPDT=DP*DT
      GO TO (3,2,1),ND
    1 CONTINUE
      IF(K.GT.KS) A(3,I,J,K-1)=A(3,I,J,K-1)-DPDT/DZFA(K-1)
      IF(K.LT.KE) A(3,I,J,K)=A(3,I,J,K)+DPDT/DZFA(K)
    2 CONTINUE
      IF(J.GT.JS) A(2,I,J-1,K)=A(2,I,J-1,K)-DPDT/DYFA(J-1)
      IF(J.LT.JE) A(2,I,J,K)=A(2,I,J,K)+DPDT/DYFA(J)
    3 CONTINUE
      IF(I.GT.IS) A(1,I-1,J,K)=A(1,I-1,J,K)-DPDT/DXFA(I-1)
      IF(I.LT.IE) A(1,I,J,K)=A(1,I,J,K)+DPDT/DXFA(I)
   20 CONTINUE
      CRT=SUM/FLOAT(NGP)
      IF(ITER.GT.ITM) GO TO 27
      IF(CRT.GT.TOL) GO TO 16
   27 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COND(DTC,TKC,TKF,MC,NC,LC,C,NCC,NFL)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL83/ SIG,TABS
      COMMON /BL87/ TFR1,TFR4
      COMMON /BL88/ EW,ESA
      COMMON /CND1/ YZ,XZ,XY,YZDX,XZDY,XYDZ
      COMMON /CND2/TC1,TC2,TC3,TC4,TC5,TC6,TC7,TC8
      COMMON /CND3/ E,TF,TA,QHI,QVI,HTP,HBP,HLP
      COMMON /CND4/ TF1,TF2,TF3,TF4,TF5,TF6
      COMMON /CND5/ IRF,ICF
      DIMENSION C(2,MC,NC,LC)
      DIMENSION NFL(MC,NC,LC)
      DIMENSION NCC(MC,NC,LC)
      DIMENSION TF1(25,25),TF2(25,25),TF3(25,25)
      DIMENSION TF4(25,25),TF5(25,25),TF6(25,25)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      DO 110 K=1,LC
      DO 110 J=1,NC
      DO 110 I=1,MC
      TS=C(1,I,J,K)
      TSR=(TS+TABS)**4
      TFR=(TF+TABS)**4
      TAR=(TA+TABS)**4
      TFR14=(TFR1+TABS)**4
      TFR44=(TFR4+TABS)**4
      NLS=NFL(I,J,K)
      GO TO(101,102,103,104,105,106,107,108),NLS
  101 CONTINUE
      QWC=(TKF*(TF1(J,K)-TS))/(DX(2)/2.0)
      QWR=EW*SIG*(TFR14-TSR)
      GO TO 107
  102 CONTINUE
      QWC=0.0
      QWR=0.0
      GO TO 107
  103 CONTINUE
      QWC=(TKF*(TF3(I,K)-TS))/(DY(2)/2.0)
      QWR=0.0
      GO TO 107
  104 CONTINUE
      QWC=(TKF*(TF4(I,K)-TS))/(DY(NM1)/2.0)
      QWR=EW*SIG*(TFR44-TSR)
      GO TO 107
  105 CONTINUE
      QWC=(TKF*(TF5(I,J)-TS))/(DZ(2)/2.0)
      QWR=0.0
      GO TO 107
  106 CONTINUE
      QWC=0.0
      QWR=0.0
      GO TO 107
  107 CONTINUE
  108 CONTINUE
      IF(IRF.EQ.0) QWR=0.0
      IF(ICF.EQ.0) QWC=0.0
      IF(J.EQ.NC) QI=QHI
      IF(J.LT.NC) QI=QVI
      IF(J.EQ.NC) H=HTP
      IF(J.LT.NC) H=HLP
      QW=QWC+QWR
      QA=ESA*SIG*(TAR-TSR)
      QR=E*SIG*(TFR-TSR)
      QC=H*(TA-TS)
      QS=QR+QC+QI+QA
      QSH=QS/2.0
```

```
      IF(NLS.EQ.8) QS=0.0
      IF(J.EQ.NIL.AND.NLS.EQ.8) QS=QSH
      IF(J.NE.NC) GO TO 201
      QB=0.025*SIG*(TAR-TSR)
      QSB=QB+QC+QI
      IF(I.EQ.5.AND.K.EQ.5) QS=QSB
  201 CONTINUE
      C1=DTC*YZ*QW
      C2=DTC*YZ*QW
      C3=DTC*XZ*QW
      C4=DTC*XZ*QW
      C5=DTC*XY*QW
      C6=DTC*XY*QW
      R1=DTC*YZ*QS
      R2=DTC*YZ*QS
      R3=DTC*XZ*QS
      R4=DTC*XZ*QS
      R5=DTC*XY*QS
      R6=DTC*XY*QS
      TIP=0.0
      TIM=0.0
      TJP=0.0
      TJM=0.0
      TKP=0.0
      TKM=0.0
      IF(I.LT.MC) TIP=C(1,I+1,J,K)-C(1,I,J,K)
      IF(I.GT.1) TIM=C(1,I-1,J,K)-C(1,I,J,K)
      IF(J.LT.NC) TJP=C(1,I,J+1,K)-C(1,I,J,K)
      IF(J.GT.1) TJM=C(1,I,J-1,K)-C(1,I,J,K)
      IF(K.LT.LC) TKP=C(1,I,J,K+1)-C(1,I,J,K)
      IF(K.GT.1) TKM=C(1,I,J,K-1)-C(1,I,J,K)
      HL1=DTC*(TKC*(YZDX*TIP+XZDY*TJP+XYDZ*TKP))
      HL2=DTC*(TKC*(YZDX*TIP+XZDY*TJM+XYDZ*TKP))
      HL3=DTC*(TKC*(YZDX*TIM+XZDY*TJP+XYDZ*TKP))
      HL4=DTC*(TKC*(YZDX*TIM+XZDY*TJM+XYDZ*TKP))
      HL5=DTC*(TKC*(YZDX*TIM+XZDY*TJP+XYDZ*TKM))
      HL6=DTC*(TKC*(YZDX*TIM+XZDY*TJM+XYDZ*TKM))
      HL7=DTC*(TKC*(YZDX*TIP+XZDY*TJP+XYDZ*TKM))
      HL8=DTC*(TKC*(YZDX*TIP+XZDY*TJM+XYDZ*TKM))
      NCS=NCC(I,J,K)
      GO TO
     !(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,
     !16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,
     !31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,
     !46,47,48,49,50,51,52),NCS
    1 CONTINUE
      RBC=R1+R4
      HL=HL8+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    2 CONTINUE
      RBC=2.0*R1+2.0*R4
      HL=HL2+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    3 CONTINUE
      RBC=R1+R4+R5
      HL=HL2+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    4 CONTINUE
      RBC=2.0*R4
      HL=HL6+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    5 CONTINUE
```

```
      RBC=4.0*R4
      HL=HL2+HL4+HL6+HL8+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
    6 CONTINUE
      RBC=2.0*R4+2.0*R5
      HL=HL2+HL4+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    7 CONTINUE
      RBC=R4
      HL=HL6+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    8 CONTINUE
      RBC=2.0*R4
      HL=HL4+HL6+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    9 CONTINUE
      RBC=R4+R5
      HL=HL4+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   10 CONTINUE
      RBC=4.0*R1
      HL=HL1+HL2+HL7+HL8+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   11 CONTINUE
      RBC=2.0*R1+2.0*R5
      HL=HL1+HL2+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   12 CONTINUE
      RBC=4.0*R5
      HL=HL1+HL2+HL3+HL4+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   13 CONTINUE
      RBC=2.0*R5
      HL=HL3+HL4+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   14 CONTINUE
      HL=HL3+HL4+HL5+HL6
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   15 CONTINUE
      RBC=2.0*R1
      HL=HL7+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   16 CONTINUE
      HL=HL5+HL6+HL7+HL8
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   17 CONTINUE
      CBC=2.0*C2
      HL=HL5+HL6+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   18 CONTINUE
      HL=HL5+HL6
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
```

```
19 CONTINUE
   HL=HL5+HL6
   S=(HL/TC2)+C(1,I,J,K)
   GO TO 100
20 CONTINUE
   RBC=R1
   HL=HL7+RBC
   S=(HL/TC1)+C(1,I,J,K)
   GO TO 100
21 CONTINUE
   RBC=2.0*R1
   HL=HL1+HL7+RBC
   S=(HL/TC2)+C(1,I,J,K)
   GO TO 100
22 CONTINUE
   RBC=R1+R5
   HL=HL1+RBC
   S=(HL/TC1)+C(1,I,J,K)
   GO TO 100
23 CONTINUE
   RBC=0.0
   HL=HL5+HL7+RBC
   S=(HL/TC2)+C(1,I,J,K)
   GO TO 100
24 CONTINUE
   RBC=0.0
   HL=HL1+HL3+HL5+HL7+RBC
   S=(HL/TC4)+C(1,I,J,K)
   GO TO 100
25 CONTINUE
   RBC=2.0*R5
   HL=HL1+HL3+RBC
   S=(HL/TC2)+C(1,I,J,K)
   GO TO 100
26 CONTINUE
   RBC=0.0
   HL=HL5+RBC
   S=(HL/TC1)+C(1,I,J,K)
   GO TO 100
27 CONTINUE
   RBC=0.0
   HL=HL3+HL5+RBC
   S=(HL/TC2)+C(1,I,J,K)
   GO TO 100
28 CONTINUE
   RBC=R5
   HL=HL3+RBC
   S=(HL/TC1)+C(1,I,J,K)
   GO TO 100
29 CONTINUE
   CBC=C2+C3
   HL=HL5+HL6+HL7+CBC
   S=(HL/TC3)+C(1,I,J,K)
   GO TO 100
30 CONTINUE
   CBC=2.0*C2+2.0*C3
   HL=HL1+HL3+HL4+HL5+HL6+HL7+CBC
   S=(HL/TC6)+C(1,I,J,K)
   GO TO 100
31 CONTINUE
   CBC=C2+C3+C6
   HL=HL1+HL3+HL4+HL5+HL6+HL7+HL8+CBC
   S=(HL/TC7)+C(1,I,J,K)
   GO TO 100
32 CONTINUE
   CBC=2.0*C3
```

```
      HL=HL5+HL7+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   33 CONTINUE
      CBC=4.0*C3
      HL=HL1+HL3+HL5+HL7+CBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   34 CONTINUE
      CBC=2.0*C3+2.0*C6
      HL=HL1+HL3+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   35 CONTINUE
      CBC=C3
      HL=HL5+CBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   36 CONTINUE
      CBC=2.0*C3
      HL=HL3+HL5+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   37 CONTINUE
      CBC=C3+C6
      HL=HL3+HL5+HL6+CBC
      S=(HL/TC3)+C(1,I,J,K)
      GO TO 100
   38 CONTINUE
      CBC=4.0*C2
      HL=HL3+HL4+HL5+HL6+CBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   39 CONTINUE
      CBC=2.0*C2+2.0*C6
      HL=HL3+HL4+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   40 CONTINUE
      CBC=4.0*C6
      HL=HL5+HL6+HL7+HL8+CBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   41 CONTINUE
      CBC=2.0*C6
      HL=HL5+HL6+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   42 CONTINUE
      CBC=C2+C4
      HL=HL5+HL6+HL8+CBC
      S=(HL/TC3)+C(1,I,J,K)
      GO TO 100
   43 CONTINUE
      CBC=2.0*C2+2.0*C4
      HL=HL2+HL3+HL4+HL5+HL6+HL8+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   44 CONTINUE
      CBC=C2+C4+C6
      HL=HL2+HL3+HL4+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC7)+C(1,I,J,K)
      GO TO 100
   45 CONTINUE
      CBC=2.0*C4
      HL=HL6+HL8+CBC
```

```
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   46 CONTINUE
      CBC=4.0*C4
      HL=HL2+HL4+HL6+HL8+CBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   47 CONTINUE
      CBC=2.0*C4+2.0*C6
      HL=HL2+HL4+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   48 CONTINUE
      CBC=C4
      HL=HL6+CBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   49 CONTINUE
      CBC=2.0*C4
      HL=HL4+HL6+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   50 CONTINUE
      CBC=C4+C6
      HL=HL4+HL5+HL6+CBC
      S=(HL/TC3)+C(1,I,J,K)
      GO TO 100
   51 CONTINUE
      HL=HL1+HL2+HL3+HL4+HL5+HL6+HL7+HL8
      S=(HL/TC8)+C(1,I,J,K)
      GO TO 100
   52 CONTINUE
      GO TO 110
  100 CONTINUE
      C(2,I,J,K)=S
  110 CONTINUE
      DO 112 K=1,LC
      DO 112 J=1,NC
      DO 112 I=1,MC
      C(1,I,J,K)=C(2,I,J,K)
  112 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE NLCS(NCC,NFL,MC,NC,LC)
      COMMON /CND6/ MIL,NIL,LIL,ILD
      COMMON /CND7/ IHS,IHF,KHS,KHF,LCT
      COMMON /CND8/ IDA,KDA,NDAL
      COMMON /CND9/ IO,MCI,NCI,LCI
      DIMENSION NCC(MC,NC,LC)
      DIMENSION NFL(MC,NC,LC)
      IOP=IO+1
      IOM=IO-1
      MCP=MC+1
      NCP=NC+1
      LCP=LC+1
      MCM=MC-1
      NCM=NC-1
      LCM=LC-1
      MCIP=MCI+1
      NCIP=NCI+1
      LCIP=LCI+1
      MCIM=MCI-1
      NCIM=NCI-1
      LCIM=LCI-1
      DO 10 K=1,LC
      DO 10 J=1,NC
      DO 10 I=1,MC
      NCC(I,J,K)=51
   10 CONTINUE
      DO 15 K=1,LC
      DO 15 I=1,MC
      NCC(I,NC,K)=5
      NCC(1,NC,K)=2
      NCC(MC,NC,K)=8
      NCC(I,NC,1)=6
      NCC(I,NC,LC)=4
      NCC(1,NC,LC)=1
      NCC(1,NC,1)=3
      NCC(MC,NC,1)=9
      NCC(MC,NC,LC)=7
   15 CONTINUE
      DO 20 K=2,LCM
      DO 20 J=2,NCM
      NCC(1,J,K)=10
   20 CONTINUE
      DO 25 J=2,NCM
      DO 25 I=1,MC
      NCC(I,J,1)=12
      IF(I.EQ.1) NCC(I,J,1)=11
      IF(I.EQ.MC) NCC(I,J,1)=13
   25 CONTINUE
      DO 30 K=2,LCM
      DO 30 J=2,NCM
      NCC(MC,J,K)=14
   30 CONTINUE
      DO 35 K=IO,LC
      DO 35 J=IO,NCI
      NCC(MC,J,K)=52
   35 CONTINUE
      DO 40 J=2,NCM
      DO 40 I=1,MC
      NCC(I,J,LC)=16
      IF(I.EQ.1) NCC(I,J,LC)=15
      IF(J.GT.IO.AND.J.LT.NCI) NCC(IO,J,LC)=17
      IF(J.LT.IO) NCC(MC,J,LC)=19
      IF(J.GT.NCI) NCC(MC,J,LC)=18
   40 CONTINUE
      DO 45 K=1,LC
      DO 45 I=1,MC
```

```
      NCC(I,1,K)=24
      NCC(1,1,K)=21
      NCC(MC,1,K)=27
      NCC(I,1,1)=25
      NCC(I,1,LC)=23
      NCC(1,1,LC)=20
      NCC(1,1,1)=22
      NCC(MC,1,1)=28
      NCC(MC,1,LC)=26
   45 CONTINUE
      DO 50 K=IO,LCI
      DO 50 I=IO,MCI
      NCC(I,NCI,K)=33
      NCC(IO,NCI,K)=30
      NCC(MCI,NCI,K)=36
      NCC(I,NCI,IO)=34
      NCC(I,NCI,LCI)=32
      NCC(IO,NCI,LCI)=29
      NCC(IO,NCI,IO)=31
      NCC(MCI,NCI,IO)=37
      NCC(MCI,NCI,LCI)=35
   50 CONTINUE
      DO 55 K=IOP,LCIM
      DO 55 J=IOP,NCIM
      NCC(IO,J,K)=38
   55 CONTINUE
      DO 60 J=IOP,NCIM
      DO 60 I=IO,MCI
      NCC(I,J,IO)=40
      IF(I.EQ.IO) NCC(IO,J,IO)=39
      IF(I.EQ.MCI) NCC(MCI,J,IO)=41
   60 CONTINUE
      DO 65 K=IO,LCI
      DO 65 I=IO,MCI
      NCC(I,IO,K)=46
      NCC(IO,IO,K)=43
      NCC(MCI,IO,K)=49
      NCC(I,IO,IO)=47
      NCC(I,IO,LCI)=45
      NCC(IO,IO,LCI)=42
      NCC(IO,IO,IO)=44
      NCC(MCI,IO,IO)=50
      NCC(MCI,IO,LCI)=48
   65 CONTINUE
      DO 70 K=IOP,LCI
      DO 70 J=IOP,NCIM
      DO 70 I=IOP,MCI
      NCC(I,J,K)=52
   70 CONTINUE
      DO 85 K=1,LC
      WRITE(6,75)
   75 FORMAT(/)
      WRITE(6,76) K
   76 FORMAT(' K=',I2)
      DO 85 J=1,NC
      JT=NCP-J
      WRITE(6,80) (NCC(I,JT,K),I=1,MC)
   80 FORMAT(11I5)
   85 CONTINUE
      DO 100 K=1,LC
      DO 100 J=1,NC
      DO 100 I=1,MC
      NFL(I,J,K)=7
  100 CONTINUE
      DO 105 K=IO,LCI
      DO 105 J=IO,NCI
```

```
      NFL(IO,J,K)=1
      NFL(MCI,J,K)=2
  105 CONTINUE
      DO 110 K=IOP,LCIM
      DO 110 I=IOP,MCIM
      NFL(I,IO,K)=3
      NFL(I,NCI,K)=4
  110 CONTINUE
      DO 115 J=IO,NCI
      DO 115 I=IOP,MCIM
      NFL(I,J,IO)=5
      NFL(I,J,LCI)=6
  115 CONTINUE
C
C     IMPACT LIMITER DESIGN
C
      IF(ILD.EQ.0) GO TO 280
C
C     ENTIRE TOP SURFACE WITH IL
C
      J=NC
      DO 210 K=1,LC
      DO 210 I=1,MC
      NFL(I,J,K)=8
      GO TO (201,202),ILD
  201 CONTINUE
      IF(I.GT.MIL.AND.K.GT.LIL) NFL(I,J,K)=7
  202 CONTINUE
  210 CONTINUE
      K=1
      DO 220 J=NIL,NC
      DO 220 I=1,MC
      NFL(I,J,K)=8
  220 CONTINUE
      I=1
      DO 230 K=1,LCT
      DO 230 J=NIL,NC
      NFL(I,J,K)=8
  230 CONTINUE
C
C     IL BOLT HOLES
C
      J=NC
      DO 235 K=KHS,KHF
      DO 235 I=IHS,IHF
      NFL(I,J,K)=7
  235 CONTINUE
C
C     ADDITIONAL INSULATION AT CUT OUT
C
      NFL(1,20,8)=8
      NFL(1,20,9)=8
      NFL(1,20,10)=8
      IF(NDAL.EQ.0) GO TO 280
C
C     DAMAGED IL
C
      DO 250 K=1,KDA
      DO 250 I=1,IDA
      NFL(I,21,K)=7
  250 CONTINUE
      DO 260 J=NIL,NC
      DO 260 I=1,IDA
      NFL(I,J,1)=7
  260 CONTINUE
      DO 270 J=NIL,NC
```

```
      NFL(1,J,2)=7
  270 CONTINUE
  280 CONTINUE
      DO 120 K=1,LC
      WRITE(6,75)
      WRITE(6,76) K
      DO 120 J=1,NC
      JT=NCP-J
      WRITE(6,80) (NFL(I,JT,K),I=1,MC)
  120 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ET(C,IO,MC,NC,LC,MCI,NCI,LCI)
      COMMON /BL5/ T1,T2,T3,T4,T5,T6
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      DIMENSION C(2,MC,NC,LC)
      DIMENSION T1(25,25),T2(25,25),T3(25,25)
      DIMENSION T4(25,25),T5(25,25),T6(25,25)
C     WRITE(6,90)
C  90 FORMAT(' WALL TEMPERATURES')
C     WRITE(6,92)
      DO 10 K=2,LM1
      KB=IO+(K-2)
      KBP=KB+1
      DO 10 J=2,NM1
      JB=IO+(J-2)
      JBP=JB+1
      TA=C(1,IO,JB,KB)+C(1,IO,JBP,KB)
      TB=C(1,IO,JB,KBP)+C(1,IO,JBP,KBP)
      T1(J,K)=(TA+TB)/4.0
      TA=C(1,MCI,JB,KB)+C(1,MCI,JBP,KB)
      TB=C(1,MCI,JB,KBP)+C(1,MCI,JBP,KBP)
      T2(J,K)=(TA+TB)/4.0
C     WRITE(6,91) J,K,T1(J,K),T2(J,K)
   10 CONTINUE
C     WRITE(6,92)
      DO 20 K=2,LM1
      KB=IO+(K-2)
      KBP=KB+1
      DO 20 I=2,MM1
      IB=IO+(I-2)
      IBP=IB+1
      TA=C(1,IB,IO,KB)+C(1,IBP,IO,KB)
      TB=C(1,IB,IO,KBP)+C(1,IBP,IO,KBP)
      T3(I,K)=(TA+TB)/4.0
      TA=C(1,IB,NCI,KB)+C(1,IBP,NCI,KB)
      TB=C(1,IB,NCI,KBP)+C(1,IBP,NCI,KBP)
      T4(I,K)=(TA+TB)/4.0
C     WRITE(6,91) I,K,T3(I,K),T4(I,K)
   20 CONTINUE
C     WRITE(6,92)
      DO 30 J=2,NM1
      JB=IO+(J-2)
      JBP=JB+1
      DO 30 I=2,MM1
      IB=IO+(I-2)
      IBP=IB+1
      TA=C(1,IB,JB,IO)+C(1,IBP,JB,IO)
      TB=C(1,IB,JBP,IO)+C(1,IBP,JBP,IO)
      T5(I,J)=(TA+TB)/4.0
      TA=C(1,IB,JB,LCI)+C(1,IBP,JB,LCI)
      TB=C(1,IB,JBP,LCI)+C(1,IBP,JBP,LCI)
      T6(I,J)=(TA+TB)/4.0
C     WRITE(6,91) I,J,T5(I,J),T6(I,J)
C  91 FORMAT(2I5,2E15.5)
C  92 FORMAT(/)
   30 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FLT(A,MCI,NCI,LCI,IO)
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /CND4/ TF1,TF2,TF3,TF4,TF5,TF6
      DIMENSION A(4,M,N,L)
      DIMENSION TF1(25,25),TF2(25,25),TF3(25,25)
      DIMENSION TF4(25,25),TF5(25,25),TF6(25,25)
      LCIM=LCI-1
      NCIM=NCI-1
      MCIM=MCI-1
      IOP=IO+1
      DO 10 K=IOP,LCIM
      KB=K-IO+1
      DO 10 J=IOP,NCIM
      JB=J-IO+1
      TFA=A(4,2,JB,KB)+A(4,2,JB,KB+1)
      TFB=A(4,2,JB+1,KB)+A(4,2,JB+1,KB+1)
      TF1(J,K)=(TFA+TFB)/4.0
      TFA=A(4,MM1,JB,KB)+A(4,MM1,JB,KB+1)
      TFB=A(4,MM1,JB+1,KB)+A(4,MM1,JB+1,KB+1)
      TF2(J,K)=(TFA+TFB)/4.0
   10 CONTINUE
      DO 20 K=IOP,LCIM
      KB=K-IO+1
      DO 20 I=IOP,MCIM
      IB=I-IO+1
      TFA=A(4,IB,2,KB)+A(4,IB,2,KB+1)
      TFB=A(4,IB+1,2,KB)+A(4,IB+1,2,KB+1)
      TF3(I,K)=(TFA+TFB)/4.0
      TFA=A(4,IB,NM1,KB)+A(4,IB,NM1,KB+1)
      TFB=A(4,IB+1,NM1,KB)+A(4,IB+1,NM1,KB+1)
      TF4(I,K)=(TFA+TFB)/4.0
   20 CONTINUE
      DO 30 J=IOP,NCIM
      JB=J-IO+1
      DO 30 I=IOP,MCIM
      IB=I-IO+1
      TFA=A(4,IB,JB,2)+A(4,IB+1,JB,2)
      TFB=A(4,IB,JB+1,2)+A(4,IB+1,JB+1,2)
      TF5(I,J)=(TFA+TFB)/4.0
      TFA=A(4,IB,JB,LM1)+A(4,IB+1,JB,LM1)
      TFB=A(4,IB,JB+1,LM1)+A(4,IB+1,JB+1,LM1)
      TF6(I,J)=(TFA+TFB)/4.0
   30 CONTINUE
      DO 40 J=IOP,NCIM
      JB=J-IO+1
      TF1(J,IO)=(A(4,2,JB,2)+A(4,2,JB+1,2))/2.0
      TF1(J,LCI)=(A(4,2,JB,LM1)+A(4,2,JB+1,LM1))/2.0
      TF2(J,IO)=(A(4,MM1,JB,2)+A(4,MM1,JB+1,2))/2.0
      TF2(J,LCI)=(A(4,MM1,JB,LM1)+A(4,MM1,JB+1,LM1))/2.0
   40 CONTINUE
      DO 50 K=IOP,LCIM
      KB=K-IO+1
      TF1(IO,K)=(A(4,2,2,KB)+A(4,2,2,KB+1))/2.0
      TF1(NCI,K)=(A(4,2,NM1,KB)+A(4,2,NM1,KB+1))/2.0
      TF2(IO,K)=(A(4,MM1,2,KB)+A(4,MM1,2,KB+1))/2.0
      TF2(NCI,K)=(A(4,MM1,NM1,KB)+A(4,MM1,NM1,KB+1))/2.0
   50 CONTINUE
      DO 60 I=IOP,MCIM
      IB=I-IO+1
      TF5(I,IO)=(A(4,IB,2,2)+A(4,IB+1,2,2))/2.0
      TF5(I,NCI)=(A(4,IB,NM1,2)+A(4,IB+1,NM1,2))/2.0
      TF6(I,IO)=(A(4,IB,2,LM1)+A(4,IB+1,2,LM1))/2.0
      TF6(I,NCI)=(A(4,IB,NM1,LM1)+A(4,IB+1,NM1,LM1))/2.0
   60 CONTINUE
      TF1(IO,IO)=A(4,2,2,2)
```

```
      TF1(NCI,IO)=A(4,2,NM1,2)
      TF1(IO,LCI)=A(4,2,2,LM1)
      TF1(NCI,LCI)=A(4,2,NM1,LM1)
      TF2(IO,IO)=A(4,MM1,2,2)
      TF2(NCI,IO)=A(4,MM1,NM1,2)
      TF2(IO,LCI)=A(4,MM1,2,LM1)
      TF2(NCI,LCI)=A(4,MM1,NM1,LM1)
      GO TO 90
   65 CONTINUE
      WRITE(6,70)
   70 FORMAT(' FLUID TEMPERATURES')
      DO 71 K=IO,LCI
      DO 71 J=IO,NCI
      WRITE(6,75) J,K,TF1(J,K),TF2(J,K)
   71 CONTINUE
      WRITE(6,80)
      DO 72 K=IO,LCI
      DO 72 I=IO,MCI
      WRITE(6,75) I,K,TF3(I,K),TF4(I,K)
   72 CONTINUE
      WRITE(6,80)
      DO 73 J=IO,NCI
      DO 73 I=IO,MCI
      WRITE(6,75) I,J,TF5(I,J),TF6(I,J)
   73 CONTINUE
   75 FORMAT(2I5,2E15.5)
      WRITE(6,80)
   80 FORMAT(/)
   90 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TAVF(A)
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL85/ M1,M2,N1,N2,K1,K2
      COMMON /BL87/ TFR1,TFR4
      DIMENSION A(4,M,N,L)
      ICNT=0
      SUMF=0.0
      DO 10 K=2,LM1
      DO 10 J=2,N2
      ICNT=ICNT+1
      SUMF=SUMF+A(4,M1,J,K)
   10 CONTINUE
      TFR1=SUMF/FLOAT(ICNT)
      ICNT=0
      SUMF=0.0
      DO 20 K=2,LM1
      DO 20 I=M1,MM1
      ICNT=ICNT+1
      SUMF=SUMF+A(4,I,N2,K)
   20 CONTINUE
      TFR4=SUMF/FLOAT(ICNT)
      RETURN
      END
```

```
      SUBROUTINE TAVW(C,IO,MC,NC,LC,MCI,NCI,LCI)
      COMMON /BL86/ TWR1,TWR4
      DIMENSION C(2,MC,NC,LC)
      ICNT=0
      SUMW=0.0
      DO 10 K=IO,LCI
      DO 10 J=IO,NCI
      ICNT=ICNT+1
      SUMW=SUMW+C(1,IO,J,K)
   10 CONTINUE
      TWR1=SUMW/FLOAT(ICNT)
      ICNT=0
      SUMW=0.0
      DO 20 K=IO,LCI
      DO 20 I=IO,MCI
      ICNT=ICNT+1
      SUMW=SUMW+C(1,I,NCI,K)
   20 CONTINUE
      TWR4=SUMW/FLOAT(ICNT)
      RETURN
      END
```

```
      SUBROUTINE NCRAD(NCR)
      COMMON /BL6/ M,N,L
      COMMON /BL85/ M1,M2,N1,N2,K1,K2
      DIMENSION NCR(M,N,L)
      DO 10 K=K1,K2
      DO 10 J=N1,N2
      DO 10 I=M1,M2
      NCR(I,J,K)=27
   10 CONTINUE
      DO 20 J=N1,N2
      DO 20 I=M1,M2
      NCR(I,J,K1)=26
      NCR(I,J,K2)=25
   20 CONTINUE
      DO 30 K=K1,K2
      DO 30 I=M1,M2
      NCR(I,N1,K)=20
      IF(K.EQ.K1) NCR(I,N1,K)=21
      IF(K.EQ.K2) NCR(I,N1,K)=19
      NCR(I,N2,K)=23
      IF(K.EQ.K1) NCR(I,N2,K)=24
      IF(K.EQ.K2) NCR(I,N2,K)=22
   30 CONTINUE
      DO 40 K=K1,K2
      DO 40 J=N1,N2
      NCR(M1,J,K)=5
      IF(K.EQ.K1) NCR(M1,J,K)=8
      IF(K.EQ.K2) NCR(M1,J,K)=2
      IF(J.EQ.N1) NCR(M1,J,K)=4
      IF(J.EQ.N2) NCR(M1,J,K)=6
      NCR(M2,J,K)=14
      IF(K.EQ.K1) NCR(M2,J,K)=17
      IF(K.EQ.K2) NCR(M2,J,K)=11
      IF(J.EQ.N1) NCR(M2,J,K)=13
      IF(J.EQ.N2) NCR(M2,J,K)=15
   40 CONTINUE
      NCR(M1,N1,K1)=7
      NCR(M1,N1,K2)=1
      NCR(M1,N2,K1)=9
      NCR(M1,N2,K2)=3
      NCR(M2,N1,K1)=16
      NCR(M2,N1,K2)=10
      NCR(M2,N2,K1)=18
      NCR(M2,N2,K2)=12
      DO 50 K=K1,K2
      WRITE(6,42) K
   42 FORMAT(' K=',I5)
      DO 50 J=N1,N2
      JT=N1+N2-J
      WRITE(6,44) (NCR(I,JT,K),I=M1,M2)
   44 FORMAT(8I5)
   50 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RAD(NCR,T,QR,EHC,EIFR)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL6/ M,N,L
      COMMON /BL83/ SIG,TABS
      COMMON /BL84/ ESFR
      COMMON /BL85/ M1,M2,N1,N2,K1,K2
      COMMON /BL86/ TWR1,TWR4
      DIMENSION T(M,N,L),QR(M,N,L),NCR(M,N,L)
      DIMENSION EIFR(M,N,L)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      TWR=(TWR1+TWR4)/2.0
      TAS=(TWR+TABS)**4
      DO 40 K=K1,K2
      DO 40 J=N1,N2
      DO 40 I=M1,M2
      AXY=DX(I)*DY(J)
      AXZ=DX(I)*DZ(K)
      AYZ=DY(J)*DZ(K)
      DV=DX(I)*DY(J)*DZ(K)
      TES=(T(I,J,K)+TABS)**4
      ISR=NCR(I,J,K)
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,
     !13,14,15,16,17,18,19,20,21,22,23,24,25,26,27),ISR
    1 CONTINUE
      AS=AYZ
      AF=2.0*AXY+AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+2.0*T(I,J,K-1))/4.0
      GO TO 30
    2 CONTINUE
      AS=AYZ
      AF=2.0*AXY+2.0*AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+T(I,J-1,K)+2.0*T(I,J,K-1))/5.0
      GO TO 30
    3 CONTINUE
      AS=AXZ+AYZ
      AF=2.0*AXY+AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J-1,K)+2.0*T(I,J,K-1))/4.0
      GO TO 30
    4 CONTINUE
      AS=AYZ
      AF=2.0*AXY+AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+T(I,J,K+1)+T(I,J,K-1))/4.0
      GO TO 30
    5 CONTINUE
      AS=AYZ
      AF=2.0*AXY+2.0*AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1)+T(I,J,K-1))/5.0
      GO TO 30
    6 CONTINUE
      AS=AXZ+AYZ
      AF=AXZ+2.0*AXY+AYZ
      TAV=(T(I+1,J,K)+T(I,J-1,K)+T(I,J,K+1)+T(I,J,K-1))/4.0
      GO TO 30
    7 CONTINUE
      AS=AYZ
      AF=AXY+AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+T(I,J,K+1))/3.0
      GO TO 30
    8 CONTINUE
      AS=AYZ
      AF=AXY+2.0*AXZ+AYZ
      TAV=(T(I+1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1))/4.0
      GO TO 30
    9 CONTINUE
      AS=AYZ
      AF=AXY+AXZ+AYZ
```

```
      TAV=(T(I+1,J,K)+T(I,J-1,K)+T(I,J,K+1))/3.0
      GO TO 30
   10 CONTINUE
      AS=0.0
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+2.0*T(I,J,K-1))/5.0
      GO TO 30
   11 CONTINUE
      AS=0.0
      AF=2.0*AXY+2.0*AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+2.0*T(I,J,K-1))/6.0
      GO TO 30
   12 CONTINUE
      AS=AXZ
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J-1,K)+2.0*T(I,J,K-1))/5.0
      GO TO 30
   13 CONTINUE
      AS=0.0
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+T(I,J,K+1)+T(I,J,K-1))/5.0
      GO TO 30
   14 CONTINUE
      AS=0.0
      AF=2.0*AXY+2.0*AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1)+T(I,J,K-1))
     !/6.0
      GO TO 30
   15 CONTINUE
      AS=AXZ
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J-1,K)+T(I,J,K+1)+T(I,J,K-1))/5.0
      GO TO 30
   16 CONTINUE
      AS=0.0
      AF=AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+T(I,J,K+1))/4.0
      GO TO 30
   17 CONTINUE
      AS=0.0
      AF=AXY+2.0*AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1))/5.0
      GO TO 30
   18 CONTINUE
      AS=AXZ
      AF=AXY+AXZ+2.0*AYZ
      TAV=(2.0*T(I-1,J,K)+T(I,J-1,K)+T(I,J,K+1))/4.0
      GO TO 30
   19 CONTINUE
      AS=0.0
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+2.0*T(I,J,K-1))/5.0
      GO TO 30
   20 CONTINUE
      AS=0.0
      AF=2.0*AXY+2.0*AYZ+AXZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+T(I,J,K+1)+T(I,J,K-1))/5.0
   21 CONTINUE
      AS=0.0
      AF=AXY+2.0*AYZ+AXZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+T(I,J,K+1))/4.0
      GO TO 30
   22 CONTINUE
      AS=AXZ
      AF=2.0*AXY+AXZ+2.0*AYZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J-1,K)+2.0*T(I,J,K-1))/5.0
```

```
      GO TO 30
   23 CONTINUE
      AS=AXZ
      AF=2.0*AXY+2.0*AYZ+AXZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J-1,K)+T(I,J,K+1)+T(I,J,K-1))/5.0
      GO TO 30
   24 CONTINUE
      AS=AXZ
      AF=AXY+2.0*AYZ+AXZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J-1,K)+T(I,J,K+1))/4.0
      GO TO 30
   25 CONTINUE
      AS=0.0
      AF=2.0*AXY+2.0*AXZ+2.0*AYZ
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+2.0*T(I,J,K-1))
     !/6.0
      GO TO 30
   26 CONTINUE
      AS=0.0
      AF=2.0*AXZ+2.0*AYZ+AXY
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1))/5.0
      GO TO 30
   27 CONTINUE
      AS=0.0
      AF=2.0*(AXY+AXZ+AYZ)
      TAV=(T(I+1,J,K)+T(I-1,J,K)+T(I,J+1,K)+T(I,J-1,K)+T(I,J,K+1)+
     !T(I,J,K-1))/6.0
   30 CONTINUE
      TAB=(TAV+TABS)**4
      QR1=(SIG*EIFR(I,J,K)*AF*(TES-TAB))/DV
      QR2=(SIG*ESFR*AS*(TES-TAS))/DV
      QR(I,J,K)=(QR1+QR2)/EHC
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WRITE(TIMC,TIME,C,U,V,W,T,P,MC,NC,LC)
      COMMON /BL6/ M,N,L
      DIMENSION C(2,MC,NC,LC)
      DIMENSION U(M,N,L),V(M,N,L),W(M,N,L),T(M,N,L)
      DIMENSION P(M,N,L)
      WRITE(9,30) TIMC
      DO 10 K=1,LC
      DO 10 J=1,NC
      DO 10 I=1,MC
      WRITE(9,30) C(1,I,J,K)
   10 CONTINUE
      WRITE(9,30) TIME
      DO 20 K=1,L
      DO 20 J=1,N
      DO 20 I=1,M
      WRITE(9,40)
     !U(I,J,K),V(I,J,K),W(I,J,K),T(I,J,K),P(I,J,K)
   20 CONTINUE
   30 FORMAT(E14.5)
   40 FORMAT(5E14.5)
      RETURN
      END
```

```
      SUBROUTINE READ(TIMC,TIME,C,U,V,W,T,P,A,MC,NC,LC)
      COMMON /BL6/ M,N,L
      DIMENSION C(2,MC,NC,LC)
      DIMENSION U(M,N,L),V(M,N,L),W(M,N,L),T(M,N,L)
      DIMENSION P(M,N,L)
      DIMENSION A(4,M,N,L)
      READ(5,30) TIMC
      DO 10 K=1,LC
      DO 10 J=1,NC
      DO 10 I=1,MC
      READ(5,30) C(1,I,J,K)
   10 CONTINUE
      READ(5,30) TIME
      DO 20 K=1,L
      DO 20 J=1,N
      DO 20 I=1,M
      READ(5,40)
     !U(I,J,K),V(I,J,K),W(I,J,K),T(I,J,K),P(I,J,K)
      A(1,I,J,K)=U(I,J,K)
      A(2,I,J,K)=V(I,J,K)
      A(3,I,J,K)=W(I,J,K)
      A(4,I,J,K)=T(I,J,K)
   20 CONTINUE
   30 FORMAT(E14.5)
   40 FORMAT(5E14.5)
      RETURN
      END
```

```
      SUBROUTINE CVR(TA,TSG,STP,SBP,SLP,HTP,HBP,HLP)
      COMMON /PRTS/ RA,TKAB,VISS,VISH,BET,CPA,GRV
      COMMON /BL91/ RL1,RL2,RL3,RL4,RL5
      COMMON /BL92/ RU1,RU2,RU3,RU4,RU5
      COMMON /BL93/ RYT,RYB,RYL
      FTA=1.8*TA+32.0
      FTSG=1.8*TSG+32.0
      FSTP=STP/0.3048
      FSBP=SBP/0.3048
      FSLP=SLP/0.3048
      CALL AIR(FTA,FTSG,TF,TSTA)
      CALL HTC(FSTP,FSBP,FSLP,TSTA,HTP,HBP,HLP)
      HTP=5.678*HTP
      HBP=5.678*HBP
      HLP=5.678*HLP
      RETURN
      END
```

```
      SUBROUTINE AIR(TA,TSG,TF,TSTA)
      COMMON /PRTS/ RA,TKAB,VISS,VISH,BET,CPA,GRV
      DATA CPA/0.24/
      DATA GRV/32.2/
      DATA RGA,PRS/53.35,14.7/
      DATA C0,C,C1,CF/0.632,245.0,-12.0,1.0E-5/
      DATA A0,A1,A2/4.0201,7.4582E-1,-5.7171E-4/
      DATA A3,A4/2.9928E-7,-6.2524E-11/
      TSTA=TSG-TA
      TF=(TSG+TA)/2.0
      TDR=TF+459.69
      TDK=(5.0/9.0)*TDR
      BET=1.0/TDR
      RA=(PRS*144.0)/(RGA*TDR)
      CT=C/TDK
      CT1=C1/TDK
      CTC=CT*(10.0**CT1)
      TKAC=(CF*C0*SQRT(TDK))/(1.0+CTC)
      TKAB=241.908*TKAC
      VISC=A0+A1*TDK+A2*TDK**2+A3*TDK**3+A4*TDK**4
      VISH=0.00024191*VISC
      VISS=VISH/3600.0
      RETURN
      END
```

```
      SUBROUTINE HTC(ST,SB,SL,TSTA,HT,HB,HL)
      COMMON /PRTS/ RA,TKAB,VISS,VISH,BET,CPA,GRV
      COMMON /BL91/ RL1,RL2,RL3,RL4,RL5
      COMMON /BL92/ RU1,RU2,RU3,RU4,RU5
      COMMON /BL93/ RYT,RYB,RYL
      DATA RL1,RU1/1.0E5,2.0E7/
      DATA RL2,RU2/2.0E7,3.0E10/
      DATA RL3,RU3/3.0E5,3.0E10/
      DATA RL4,RU4/1.0E5,1.0E9/
      DATA RL5,RU5/1.0E9,1.0E12/
      GRF=(RA**2*GRV*BET*TSTA)/(VISS**2)
      GRL=GRF*SL**3
      GRB=GRF*SB**3
      GRT=GRF*ST**3
      PR=(CPA*VISH)/TKAB
      RYL=GRL*PR
      RYB=GRB*PR
      RYT=GRT*PR
      IF(TSTA.LE.0.0) GO TO 5
      IF(RYT.GE.RL1.AND.RYT.LE.RU1) HNUT=0.54*RYT**0.25
      IF(RYT.GT.RL2.AND.RYT.LE.RU2) HNUT=0.14*RYT**0.33333
      IF(RYB.GE.RL3.AND.RYB.LE.RU3) HNUB=0.27*RYB**0.25
      IF(GRL.LT.RL4) HNUL=0.48*GRL**0.25
      IF(RYL.GE.RL4.AND.RYL.LE.RU4) HNUL=0.555*RYL**0.25
      IF(RYL.GT.RL5.AND.RYL.LE.RU5) HNUL=0.021*RYL**0.4
      HT=(TKAB*HNUT)/ST
      HB=(TKAB*HNUB)/SB
      HL=(TKAB*HNUL)/SL
    5 CONTINUE
      RETURN
      END
```

APPENDIX B

COMPUTER CODE TAF-RD

This Appendix presents only the main program and one subroutine of the computer code TAF-RD (Thermal Analysis Fire for RD fuel) which was used to perform the fire accident analysis of a road cask during the 0.5 hour fire. All other subroutines are the same with those of the computer code TAN-RD (see Appendix A).

```
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL2/ R,B,VK,THD,CP
      COMMON /BL3/ CR,ETD
      COMMON /BL4/ DT
      COMMON /BL5/ T1,T2,T3,T4,T5,T6
      COMMON /BL6/ M,N,L
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL8/ TR,G
      COMMON /BL9/ ND
      COMMON /BL10/ I,J,K
      COMMON /BL11/ A11,A12,A13,X33,XM323,XP323
      COMMON /BL12/ A11M,A12M,A13M,X33M,XM323M,XP323M
      COMMON /BL21/ B11,B12,B13,Y33,YM323,YP323
      COMMON /BL22/ B11N,B12N,B13N,Y33N,YM323N,YP323N
      COMMON /BL31/ C11,C12,C13,Z33,ZM323,ZP323
      COMMON /BL32/ C11L,C12L,C13L,Z33L,ZM323L,ZP323L
      COMMON /BL51/ FKU,FKV,FKW
      COMMON /BL52/ SPD
      COMMON /BL53/ TDIA
      COMMON /BL54/ RD1,RD2,RD3,RD4
      COMMON /BL55/ CST1,CST2,CST3,CST4
      COMMON /BL56/ EX2,EX3,EX4
      COMMON /BL57/ UC,VC,WC
      COMMON /BL58/ IS,IE,JS,JE,KS,KE
      COMMON /BL59/ TOL,CRT,ITM,NGP,ITER
      COMMON /BL60/ IFU,IFV,IFW,IFT
      COMMON /BL61/ EPR
      COMMON /BL71/ IDXS,JDYS
      COMMON /BL72/ DXP,DYP,DZP
      COMMON /BL83/ SIG,TABS
      COMMON /BL84/ ESFR
      COMMON /BL85/ M1,M2,N1,N2,K1,K2
      COMMON /BL86/ TWR1,TWR4
      COMMON /BL87/ TFR1,TFR4
      COMMON /BL88/ EW,ESA
      COMMON /BL91/ RL1,RL2,RL3,RL4,RL5
      COMMON /BL92/ RU1,RU2,RU3,RU4,RU5
      COMMON /BL93/ RYT,RYB,RYL
      COMMON /BLS/ S1,S2,S3,S4,S5,S6
      COMMON /CND1/ YZ,XZ,XY,YZDX,XZDY,XYDZ
      COMMON /CND2/ TC1,TC2,TC3,TC4,TC5,TC6,TC7,TC8
      COMMON /CND3/ E,TF,TA,QHI,QVI,HTP,HBP,HLP
      COMMON /CND4/ TF1,TF2,TF3,TF4,TF5,TF6
      COMMON /CND5/ IRF,ICF
      COMMON /CND6/ MIL,NIL,LIL,ILD
      COMMON /CND7/ IHS,IHF,KHS,KHF,LCT
      COMMON /CND8/ IDA,KDA,NDAL
      COMMON /CND9/ IO,MCI,NCI,LCI
      DIMENSION A(4,9,16,8)
      DIMENSION U(9,16,8),V(9,16,8),W(9,16,8),P(9,16,8),T(9,16,8)
      DIMENSION Q(9,16,8),NCP(9,16,8),DFDP(9,16,8)
      DIMENSION UP(9,16),VP(9,16),TP(9,16)
      DIMENSION QR(9,16,8)
      DIMENSION NCR(9,16,8)
      DIMENSION EIFR(9,16,8)
      DIMENSION T1(25,25),T2(25,25),T3(25,25)
      DIMENSION T4(25,25),T5(25,25),T6(25,25)
      DIMENSION TF1(25,25),TF2(25,25),TF3(25,25)
      DIMENSION TF4(25,25),TF5(25,25),TF6(25,25)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      DIMENSION XX(50),YY(50),ZZ(50)
      DIMENSION DFDP1(50),DFDP2(50),DFDP3(50)
      DIMENSION DXP(50),DYP(50),DZP(50)
      DIMENSION C(2,11,21,10)
      DIMENSION NCC(11,21,10)
      DIMENSION NFL(11,21,10)
```

```
C
C       DATA FOR RADIATIVE HEAT TRANSFER
C
        DATA IRF/1/
        DATA EB,ESFR/2*0.7/
C
C       DATA FOR CONVECTIVE HEAT TRANSFER
C
        DATA (DX(I),I=1,9)/9*0.095/
        DATA (DY(J),J=1,16)/16*0.09/
        DATA (DZ(K),K=1,8)/8*0.088/
        DATA M,N,L/9,16,8/
        DATA M1,M2,N1,N2,K1,K2/2,8,2,13,2,7/
        DATA II1,II2,JJ1,JJ2,KK1,KK2/4,8,4,7,6,7/
        DATA IR1,IR2,JR1,JR2,KR1,KR2/4,8,4,7,6,7/
        DATA R,CP,TK,VK,B,THD/962.2,4186.8,120.0,3.168E-7,7.2E-4,1.69E-7/
        DATA RS,CPS,TKS/5312.0,676.9,120.0/
        DATA TR/38.0/
        DATA CST1,CST2,CST3,CST4/9.0E-4,1.3022E-3,8.5467E-3,34.93E-3/
        DATA EX2,EX3,EX4/0.1605,0.62,0.8858/
        DATA IDXS,JDYS/5,2/
        DATA SCFX,SCFY/2*1.45/
        DATA IBC/1/
        DATA DT/1.0/
        DATA ND/3/
        DATA QU/99910.79/
        DATA EPR/0.059/
        DATA NS,NTS/99,50/
        DATA NCOUNT,NW/0,1/
        DATA ITM/100/
        DATA TOL/1.0E-4/
        DATA SPD/1.7/
        DATA G/9.81/
        DATA TDIA/0.1/
        DATA RD1,RD2,RD3,RD4/1.0E1,6.0E1,2.0E2,1.0E4/
        DATA UC,VC,WC/3*0.0/
        DATA NPF,NPM/1,2/
        DATA NRED/1/
        DATA NCAV/1/
        DATA NWAL/1/
        DATA NHO/5/
        DATA MSL,NSL,LSL/3,10,3/
C
C       DATA FOR HEAT CONDUCTION
C
        DATA SIG,TABS/5.669E-8,273.0/
        DATA MC,NC,LC/11,21,10/
        DATA MCI,NCI,LCI/11,18,10/
        DATA IO/4/
        DATA DXC,DYC,DZC/0.095,0.09,0.088/
        DATA TKC,RC,CPC/18.2,7817.0,500.0/
        DATA TKF/120.0/
        DATA DTC/50.0/
        DATA NSC,NTC/1,36/
        DATA EF,ES,ESA,EW/0.9,0.8,0.0,0.5/
        DATA TF/800.0/
        DATA TA,QHI,QVI/800.0,2*0.0/
        DATA MIL,NIL,LIL,ILD/11,18,10,2/
        DATA IHS,IHF,KHS,KHF,LCT/4*5,7/
        DATA NDAL/0/
        DATA IDA,KDA/2,2/
        DATA HTP,HBP,HLP/3*0.0/
        DATA STP,SBP,SLP/1.145,1.9,1.53/
        DATA ICF/1/
C
        OPEN(5,FILE='IN.DAT',STATUS='OLD')
```

```
      OPEN(6,FILE='OUT.DAT',STATUS='NEW')
      OPEN(9,FILE='SAV.DAT',STATUS='NEW')
C
C     EVALUATION OF CONSTANTS FOR HEAT CONDUCTION
C
      MM1=M-1
      NM1=N-1
      LM1=L-1
      MM2=M-2
      NM2=N-2
      LM2=L-2
      X=DXC/2.0
      Y=DYC/2.0
      Z=DZC/2.0
      YZ=Y*Z
      XZ=X*Z
      XY=X*Y
      XYZ=X*Y*Z
      YZDX=YZ/DXC
      XZDY=XZ/DYC
      XYDZ=XY/DZC
      TC=RC*CPC*XYZ
      TC1=TC
      TC2=2.0*TC
      TC3=3.0*TC
      TC4=4.0*TC
      TC5=5.0*TC
      TC6=6.0*TC
      TC7=7.0*TC
      TC8=8.0*TC
      DO 91 K=1,LC
      DO 91 J=1,NC
      DO 91 I=1,MC
      C(1,I,J,K)=TA
   91 CONTINUE
C
C     EVALUATION OF CONSTANTS FOR CONVECTION
C
      CF=R*CP
      CS=RS*CPS
      ETK=EPR*TK+(1.0-EPR)*TKS
      EHC=EPR*CF+(1.0-EPR)*CS
      ETD=ETK/EHC
      CR=CF/EHC
      XL=0.0
      YL=0.0
      DO 1 I=2,MM1
      DXP(I)=DX(I)/SCFX
      XL=XL+DXP(I)
    1 CONTINUE
      DO 2 J=2,NM1
      DYP(J)=DY(J)/SCFY
      YL=YL+DYP(J)
    2 CONTINUE
      DO 4 I=2,MM1
      DXFA(I-1)=(DX(I-1)+DX(I))/2.0
      DXFA(I)=(DX(I)+DX(I+1))/2.0
      IF(I.EQ.2) XX(I-1)=-DX(I-1)/2.0
      XX(I)=XX(I-1)+DXFA(I-1)
      DFDX1(I)=(1.0/DXFA(I-1)+1.0/DXFA(I))/DX(I)
    4 CONTINUE
      DO 5 J=2,NM1
      DYFA(J-1)=(DY(J-1)+DY(J))/2.0
      DYFA(J)=(DY(J)+DY(J+1))/2.0
      IF(J.EQ.2) YY(J-1)=-DY(J-1)/2.0
      YY(J)=YY(J-1)+DYFA(J-1)
```

```
      DFDP2(J)=(1.0/DYFA(J-1)+1.0/DYFA(J))/DY(J)
    5 CONTINUE
      DO 6 K=2,LM1
      DZFA(K-1)=(DZ(K-1)+DZ(K))/2.0
      DZFA(K)=(DZ(K)+DZ(K+1))/2.0
      IF(K.EQ.2) ZZ(K-1)=-DZ(K-1)/2.0
      ZZ(K)=ZZ(K-1)+DZFA(K-1)
      DFDP3(K)=(1.0/DZFA(K-1)+1.0/DZFA(K))/DZ(K)
    6 CONTINUE
      NGP=MM2*NM2*LM2
      GRF=0.0
      PRL=VK/THD
      RAH=GRF*PRL
      IF(IBC.EQ.1) CALL TCS1
      IF(IBC.EQ.2) CALL TCS2
C
C     INITIALIZATION OF VARIABLES
C
      DO 10 K=1,L
      DO 10 J=1,N
      DO 10 I=1,M
      U(I,J,K)=0.0
      V(I,J,K)=0.0
      W(I,J,K)=0.0
      T(I,J,K)=TR
      P(I,J,K)=1.0
      QR(I,J,K)=0.0
      Q(I,J,K)=0.0
      NCP(I,J,K)=NPF
      EIFR(I,J,K)=0.0
   10 CONTINUE
      DO 15 K=K1,K2
      DO 15 J=N1,N2
      DO 15 I=M1,M2
      NCP(I,J,K)=NPM
   15 CONTINUE
      DO 18 K=KK1,KK2
      DO 18 J=JJ1,JJ2
      DO 18 I=II1,II2
      Q(I,J,K)=QU/EHC
      IF(NHO.EQ.5) Q(I,5,7)=Q(I,5,7)/4.0
      IF(NHO.EQ.5) Q(I,6,7)=Q(I,6,7)/4.0
      WRITE(6,*) QU,EHC,Q(I,J,K)
   18 CONTINUE
      DO 19 K=KR1,KR2
      DO 19 J=JR1,JR2
      DO 19 I=IR1,IR2
      EIFR(I,J,K)=EB
   19 CONTINUE
      DO 42 K=1,L
      WRITE(6,31)
   31 FORMAT(/)
      DO 42 I=1,M
      WRITE(6,41) (NCP(I,J,K),J=1,N)
   41 FORMAT(25I5)
   42 CONTINUE
      CALL NCRAD(NCR)
C
C     SOLUTION OF HEAT CONDUCTION
C
      TIME=0.0
      TIMC=0.0
      IF(NRED.GT.0) CALL READ(TIMC,TIME,C,U,V,W,T,P,A,MC,NC,LC)
      CALL NLCS(NCC,NFL,MC,NC,LC)
      NCNT=0
      NWC=1
```

```
      IF(NWAL.EQ.0) GO TO 125
   32 CONTINUE
      TSG=(C(1,1,1,1)+C(1,1,1,LC)+C(1,1,NC,1)+C(1,1,NC,LC))/4.0
      CALL CVR(TA,TSG,STP,SBP,SLP,HTP,HBP,HLP)
      CALL FLT(A,MCI,NCI,LCI,IO)
      IF(IRF.GT.0) CALL TAVF(A)
      TIMC=TIMC+DTC
      E=1.0/(1.0/EF+1.0/ES-1.0)
      CALL CONDF(DTC,TKC,TKF,MC,NC,LC,C,NCC,NFL)
      NCNT=NCNT+1
      IF(NCNT.NE.NWC) GO TO 120
      NWC=NWC+NSC
      IF(NCNT.EQ.1) NSC=NSC+1
      WRITE(6,172)
  172 FORMAT('1')
      WRITE(6,112) TIMC
  112 FORMAT(' TIME=',E15.7)
      DO 118 K=1,LC
      WRITE(6,115)
  115 FORMAT(/)
      DO 118 J=1,NC
      JT=NC+1-J
      WRITE(6,116) (C(1,I,JT,K),I=1,MC)
  116 FORMAT(11E11.4)
  118 CONTINUE
      IF(RYT.LT.RL1.OR.RYT.GT.RU2) WRITE(6,81) RL1,RYT,RU2
      IF(RYB.LT.RL3.OR.RYB.GT.RU3) WRITE(6,82) RL3,RYB,RU3
      IF(RYL.LT.RL4.OR.RYL.GT.RU5) WRITE(6,83) RL4,RYL,RU5
   81 FORMAT(' RL1=',E12.5,2X,'RYT=',E12.5,2X,'RU2=',E12.5)
   82 FORMAT(' RL3=',E12.5,2X,'RYB=',E12.5,2X,'RU3=',E12.5)
   83 FORMAT(' RL4=',E12.5,2X,'RYL=',E12.5,2X,'RU5=',E12.5)
      WRITE(6,92) HTP,HBP,HLP
   92 FORMAT(' HTP=',E12.5,2X,'HBP=',E12.5,2X,'HLP=',E12.5)
      CALL WRITE(TIMC,TIME,C,U,V,W,T,P,MC,NC,LC)
  120 CONTINUE
  125 CONTINUE
C
C     INCREMENT OF TIME
C
      NECT=0
      IF(NCAV.EQ.0) GO TO 61
   11 CONTINUE
      NECT=NECT+1
      TIME=TIME+DT
C
C     CALCULATION OF VELOCITY FIELD
C
      DO 7 K=2,LM1
      DO 7 J=2,NM1
      DO 7 I=2,MM1
      CALL PMS(U,V,W)
      IFU=NCP(I,J,K)
      IFV=NCP(I,J,K)
      IFW=NCP(I,J,K)
      IF(I.LT.MM1) CALL US(A,U,V,W,P)
      IF(J.LT.NM1) CALL VS(A,U,V,W,P,T)
      IF(K.LT.LM1) CALL WS(A,U,V,W,P)
    7 CONTINUE
      CALL VBC(A)
C
C     CALCULATION OF PRESSURE FIELD
C
      DO 8 K=2,LM1
      DO 8 I=2,MM1
      DO 8 J=2,NM1
      DFDP(I,J,K)=DT*(DFDP1(I)+DFDP2(J)+DFDP3(K))
```

```
    8 CONTINUE
      CALL PS(A,P,DFDP)
      CALL VBC(A)
C
C     CALCULATION OF TEMPERATURE FIELD
C
      IF(IRF.GT.0) CALL TAVW(C,IO,MC,NC,LC,MCI,NCI,LCI)
      IF(IRF.GT.0) CALL RAD(NCR,T,QR,EHC,EIFR)
      DO 34 K=K1,K2
      DO 34 J=N1,N2
      DO 34 I=M1,M2
      IF(J.GT.NSL.AND.K.LE.LSL) GO TO 33
      IF(J.GT.NSL.AND.I.LE.MSL) GO TO 33
      U(I,J,K)=0.0
      V(I,J,K)=0.0
      W(I,J,K)=0.0
      A(1,I,J,K)=0.0
      A(2,I,J,K)=0.0
      A(3,I,J,K)=0.0
   33 CONTINUE
   34 CONTINUE
      DO 35 K=2,LM1
      DO 35 J=2,NM1
      DO 35 I=2,MM1
      IFT=NCP(I,J,K)
      CALL TS(A,U,V,W,T,Q,QR)
   35 CONTINUE
      CALL ET(C,IO,MC,NC,LC,MCI,NCI,LCI)
      IF(IBC.EQ.1) CALL TBC1(A)
C     IF(IBC.EQ.2) CALL TBC2(A)
C
C     UPDATING OF VARIABLES
C
      DO 50 K=1,L
      DO 50 J=1,N
      DO 50 I=1,M
      U(I,J,K)=A(1,I,J,K)
      V(I,J,K)=A(2,I,J,K)
      W(I,J,K)=A(3,I,J,K)
      T(I,J,K)=A(4,I,J,K)
   50 CONTINUE
C
C     OUTPUT OF RESULTS
C
      TBFS=0.0
      NCOUNT=NCOUNT+1
      IF(NCOUNT.NE.NW) GO TO 60
      NW=NW+NS
      IF(NCOUNT.EQ.1) NS=NS+1
      WRITE(6,72)
   72 FORMAT('1')
      WRITE(6,12) TIME
   12 FORMAT(' TIME=',E15.7)
      WRITE(6,71) NCOUNT,ITER,TOL,CRT
   71 FORMAT(' NCOUNT=',I10,' ITER=',I10,' TOL=',E15.5,' CRT=',E15.5)
      WRITE(6,56) GRF,PRL,RAH
   56 FORMAT(' GRF=',E15.5,' PRL=',E15.5,' RAH=',E15.5)
      DO 55 K=2,LM1
      WRITE(6,51)
   51 FORMAT(/)
      WRITE(6,52) ZZ(K)
   52 FORMAT(' RESULTS AT PLANE Z=',E15.4,' ')
      JM=0
      DO 55 J=2,NM1
      JM=JM+1
      WRITE(6,53) YY(J)
```

```
 53 FORMAT(' Y=',E15.4)
    IM=0
    DO 55 I=2,MM1
    IM=IM+1
    IF(ND.GE.1) UAV=0.5*(A(1,I,J,K)+A(1,I-1,J,K))
    IF(ND.GE.2) VAV=0.5*(A(2,I,J,K)+A(2,I,J-1,K))
    IF(ND.GE.3) WAV=0.5*(A(3,I,J,K)+A(3,I,J,K-1))
    UP(IM,JM)=UAV
    VP(IM,JM)=VAV
    TP(IM,JM)=A(4,I,J,K)
    WRITE(6,54)
   'I,J,K,XX(I),UAV,VAV,WAV,A(4,I,J,K),P(I,J,K)
   ',Q(I,J,K),QR(I,J,K)
 54 FORMAT(3I5,8E14.5)
    TBFS=TBFS+A(4,I,J,K)
 55 CONTINUE
    TBF=TBFS/FLOAT(NGP)
    WRITE(6,58) TBF
 58 FORMAT(' TBF=',E15.5)
 60 CONTINUE
    IF(NECT.LT.NTS) GO TO 11
 61 CONTINUE
    IF(NCNT.LT.NTC) GO TO 32
    STOP
    END
```

```
      SUBROUTINE CONDF(DTC,TKC,TKF,MC,NC,LC,C,NCC,NFL)
      COMMON /BL1/ DX,DY,DZ,DXFA,DYFA,DZFA
      COMMON /BL7/ MM1,NM1,LM1,MM2,NM2,LM2
      COMMON /BL83/ SIG,TABS
      COMMON /BL87/ TFR1,TFR4
      COMMON /BL88/ EW,ESA
      COMMON /CND1/ YZ,XZ,XY,YZDX,XZDY,XYDZ
      COMMON /CND2/TC1,TC2,TC3,TC4,TC5,TC6,TC7,TC8
      COMMON /CND3/ E,TF,TA,QHI,QVI,HTP,HBP,HLP
      COMMON /CND4/ TF1,TF2,TF3,TF4,TF5,TF6
      COMMON /CND5/ IRF,ICF
      COMMON /CND6/ MIL,NIL,LIL,ILD
      COMMON /CND7/ IHS,IHF,KHS,KHF,LCT
      DIMENSION C(2,MC,NC,LC)
      DIMENSION NFL(MC,NC,LC)
      DIMENSION NCC(MC,NC,LC)
      DIMENSION TF1(25,25),TF2(25,25),TF3(25,25)
      DIMENSION TF4(25,25),TF5(25,25),TF6(25,25)
      DIMENSION DX(50),DY(50),DZ(50),DXFA(50),DYFA(50),DZFA(50)
      DO 110 K=1,LC
      DO 110 J=1,NC
      DO 110 I=1,MC
      TS=C(1,I,J,K)
      TSR=(TS+TABS)**4
      TFR=(TF+TABS)**4
      TAR=(TA+TABS)**4
      TFR14=(TFR1+TABS)**4
      TFR44=(TFR4+TABS)**4
      NLS=NFL(I,J,K)
      GO TO(101,102,103,104,105,106,107,108),NLS
  101 CONTINUE
      QWC=(TKF*(TF1(J,K)-TS))/(DX(2)/2.0)
      QWR=EW*SIG*(TFR14-TSR)
      GO TO 107
  102 CONTINUE
      QWC=0.0
      QWR=0.0
      GO TO 107
  103 CONTINUE
      QWC=(TKF*(TF3(I,K)-TS))/(DY(2)/2.0)
      QWR=0.0
      GO TO 107
  104 CONTINUE
      QWC=(TKF*(TF4(I,K)-TS))/(DY(NM1)/2.0)
      QWR=EW*SIG*(TFR44-TSR)
      GO TO 107
  105 CONTINUE
      QWC=(TKF*(TF5(I,J)-TS))/(DZ(2)/2.0)
      QWR=0.0
      GO TO 107
  106 CONTINUE
      QWC=0.0
      QWR=0.0
      GO TO 107
  107 CONTINUE
  108 CONTINUE
      IF(IRF.EQ.0) QWR=0.0
      IF(ICF.EQ.0) QWC=0.0
      IF(J.EQ.NC) QI=QHI
      IF(J.LT.NC) QI=QVI
      IF(J.EQ.NC) H=HTP
      IF(J.LT.NC) H=HLP
      QW=QWC+QWR
      QA=ESA*SIG*(TAR-TSR)
      QR=E*SIG*(TFR-TSR)
      QC=H*(TA-TS)
```

```
      QS=QR+QC+QI+QA
      QSH=QS/2.0
      IF(NLS.EQ.8) QS=0.0
      IF(J.EQ.NIL.AND.NLS.EQ.8) QS=QSH
      IF(J.NE.NC) GO TO 201
      QB=0.025*SIG*(TFR-TSR)
      QSB=QB+QC+QI+QA
      IF(I.EQ.5.AND.K.EQ.5) QS=QSB
  201 CONTINUE
      C1=DTC*YZ*QW
      C2=DTC*YZ*QW
      C3=DTC*XZ*QW
      C4=DTC*XZ*QW
      C5=DTC*XY*QW
      C6=DTC*XY*QW
      R1=DTC*YZ*QS
      R2=DTC*YZ*QS
      R3=DTC*XZ*QS
      R4=DTC*XZ*QS
      R5=DTC*XY*QS
      R6=DTC*XY*QS
      TIP=0.0
      TIM=0.0
      TJP=0.0
      TJM=0.0
      TKP=0.0
      TKM=0.0
      IF(I.LT.MC) TIP=C(1,I+1,J,K)-C(1,I,J,K)
      IF(I.GT.1) TIM=C(1,I-1,J,K)-C(1,I,J,K)
      IF(J.LT.NC) TJP=C(1,I,J+1,K)-C(1,I,J,K)
      IF(J.GT.1) TJM=C(1,I,J-1,K)-C(1,I,J,K)
      IF(K.LT.LC) TKP=C(1,I,J,K+1)-C(1,I,J,K)
      IF(K.GT.1) TKM=C(1,I,J,K-1)-C(1,I,J,K)
      HL1=DTC*(TKC*(YZDX*TIP+XZDY*TJP+XYDZ*TKP))
      HL2=DTC*(TKC*(YZDX*TIP+XZDY*TJM+XYDZ*TKP))
      HL3=DTC*(TKC*(YZDX*TIM+XZDY*TJP+XYDZ*TKP))
      HL4=DTC*(TKC*(YZDX*TIM+XZDY*TJM+XYDZ*TKP))
      HL5=DTC*(TKC*(YZDX*TIM+XZDY*TJP+XYDZ*TKM))
      HL6=DTC*(TKC*(YZDX*TIM+XZDY*TJM+XYDZ*TKM))
      HL7=DTC*(TKC*(YZDX*TIP+XZDY*TJP+XYDZ*TKM))
      HL8=DTC*(TKC*(YZDX*TIP+XZDY*TJM+XYDZ*TKM))
      NCS=NCC(I,J,K)
      GO TO
     !(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,
     !16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,
     !31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,
     !46,47,48,49,50,51,52),NCS
    1 CONTINUE
      RBC=R1+R4
      HL=HL8+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    2 CONTINUE
      RBC=2.0*R1+2.0*R4
      HL=HL2+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    3 CONTINUE
      RBC=R1+R4+R5
      HL=HL2+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    4 CONTINUE
      RBC=2.0*R4
      HL=HL6+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
```

```
      GO TO 100
    5 CONTINUE
      RBC=4.0*R4
      HL=HL2+HL4+HL6+HL8+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
    6 CONTINUE
      RBC=2.0*R4+2.0*R5
      HL=HL2+HL4+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    7 CONTINUE
      RBC=R4
      HL=HL6+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
    8 CONTINUE
      RBC=2.0*R4
      HL=HL4+HL6+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
    9 CONTINUE
      RBC=R4+R5
      HL=HL4+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   10 CONTINUE
      RBC=4.0*R1
      HL=HL1+HL2+HL7+HL8+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   11 CONTINUE
      RBC=2.0*R1+2.0*R5
      HL=HL1+HL2+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   12 CONTINUE
      RBC=4.0*R5
      HL=HL1+HL2+HL3+HL4+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   13 CONTINUE
      RBC=2.0*R5
      HL=HL3+HL4+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   14 CONTINUE
      HL=HL3+HL4+HL5+HL6
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   15 CONTINUE
      RBC=2.0*R1
      HL=HL7+HL8+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   16 CONTINUE
      HL=HL5+HL6+HL7+HL8
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   17 CONTINUE
      CBC=2.0*C2
      HL=HL5+HL6+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   18 CONTINUE
      HL=HL5+HL6
```

```
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   19 CONTINUE
      HL=HL5+HL6
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   20 CONTINUE
      RBC=R1+R3
      HL=HL7+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   21 CONTINUE
      RBC=2.0*R1+2.0*R3
      HL=HL1+HL7+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   22 CONTINUE
      RBC=R1+R3+R5
      HL=HL1+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   23 CONTINUE
      RBC=2.0*R3
      HL=HL5+HL7+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   24 CONTINUE
      RBC=4.0*R3
      HL=HL1+HL3+HL5+HL7+RBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   25 CONTINUE
      RBC=2.0*R3+2.0*R5
      HL=HL1+HL3+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   26 CONTINUE
      RBC=R3
      HL=HL5+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   27 CONTINUE
      RBC=2.0*R3
      HL=HL3+HL5+RBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   28 CONTINUE
      RBC=R3+R5
      HL=HL3+RBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   29 CONTINUE
      CBC=C2+C3
      HL=HL5+HL6+HL7+CBC
      S=(HL/TC3)+C(1,I,J,K)
      GO TO 100
   30 CONTINUE
      CBC=2.0*C2+2.0*C3
      HL=HL1+HL3+HL4+HL5+HL6+HL7+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   31 CONTINUE
      CBC=C2+C3+C6
      HL=HL1+HL3+HL4+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC7)+C(1,I,J,K)
      GO TO 100
```

```
 32 CONTINUE
    CBC=2.0*C3
    HL=HL5+HL7+CBC
    S=(HL/TC2)+C(1,I,J,K)
    GO TO 100
 33 CONTINUE
    CBC=4.0*C3
    HL=HL1+HL3+HL5+HL7+CBC
    S=(HL/TC4)+C(1,I,J,K)
    GO TO 100
 34 CONTINUE
    CBC=2.0*C3+2.0*C6
    HL=HL1+HL3+HL5+HL6+HL7+HL8+CBC
    S=(HL/TC6)+C(1,I,J,K)
    GO TO 100
 35 CONTINUE
    CBC=C3
    HL=HL5+CBC
    S=(HL/TC1)+C(1,I,J,K)
    GO TO 100
 36 CONTINUE
    CBC=2.0*C3
    HL=HL3+HL5+CBC
    S=(HL/TC2)+C(1,I,J,K)
    GO TO 100
 37 CONTINUE
    CBC=C3+C6
    HL=HL3+HL5+HL6+CBC
    S=(HL/TC3)+C(1,I,J,K)
    GO TO 100
 38 CONTINUE
    CBC=4.0*C2
    HL=HL3+HL4+HL5+HL6+CBC
    S=(HL/TC4)+C(1,I,J,K)
    GO TO 100
 39 CONTINUE
    CBC=2.0*C2+2.0*C6
    HL=HL3+HL4+HL5+HL6+HL7+HL8+CBC
    S=(HL/TC6)+C(1,I,J,K)
    GO TO 100
 40 CONTINUE
    CBC=4.0*C6
    HL=HL5+HL6+HL7+HL8+CBC
    S=(HL/TC4)+C(1,I,J,K)
    GO TO 100
 41 CONTINUE
    CBC=2.0*C6
    HL=HL5+HL6+CBC
    S=(HL/TC2)+C(1,I,J,K)
    GO TO 100
 42 CONTINUE
    CBC=C2+C4
    HL=HL5+HL6+HL8+CBC
    S=(HL/TC3)+C(1,I,J,K)
    GO TO 100
 43 CONTINUE
    CBC=2.0*C2+2.0*C4
    HL=HL2+HL3+HL4+HL5+HL6+HL8+CBC
    S=(HL/TC6)+C(1,I,J,K)
    GO TO 100
 44 CONTINUE
    CBC=C2+C4+C6
    HL=HL2+HL3+HL4+HL5+HL6+HL7+HL8+CBC
    S=(HL/TC7)+C(1,I,J,K)
    GO TO 100
 45 CONTINUE
```

```
      CBC=2.0*C4
      HL=HL6+HL8+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   46 CONTINUE
      CBC=4.0*C4
      HL=HL2+HL4+HL6+HL8+CBC
      S=(HL/TC4)+C(1,I,J,K)
      GO TO 100
   47 CONTINUE
      CBC=2.0*C4+2.0*C6
      HL=HL2+HL4+HL5+HL6+HL7+HL8+CBC
      S=(HL/TC6)+C(1,I,J,K)
      GO TO 100
   48 CONTINUE
      CBC=C4
      HL=HL6+CBC
      S=(HL/TC1)+C(1,I,J,K)
      GO TO 100
   49 CONTINUE
      CBC=2.0*C4
      HL=HL4+HL6+CBC
      S=(HL/TC2)+C(1,I,J,K)
      GO TO 100
   50 CONTINUE
      CBC=C4+C6
      HL=HL4+HL5+HL6+CBC
      S=(HL/TC3)+C(1,I,J,K)
      GO TO 100
   51 CONTINUE
      HL=HL1+HL2+HL3+HL4+HL5+HL6+HL7+HL8
      S=(HL/TC8)+C(1,I,J,K)
      GO TO 100
   52 CONTINUE
      GO TO 110
  100 CONTINUE
      C(2,I,J,K)=S
  110 CONTINUE
      DO 112 K=1,LC
      DO 112 J=1,NC
      DO 112 I=1,MC
      C(1,I,J,K)=C(2,I,J,K)
  112 CONTINUE
      RETURN
      END
```

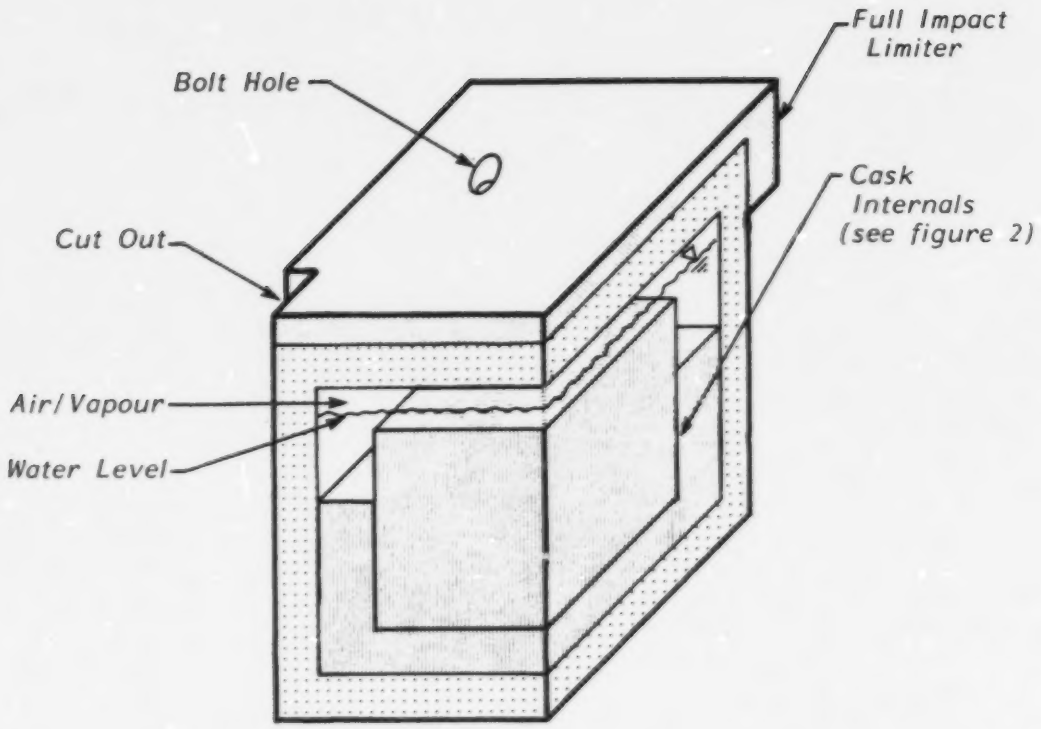
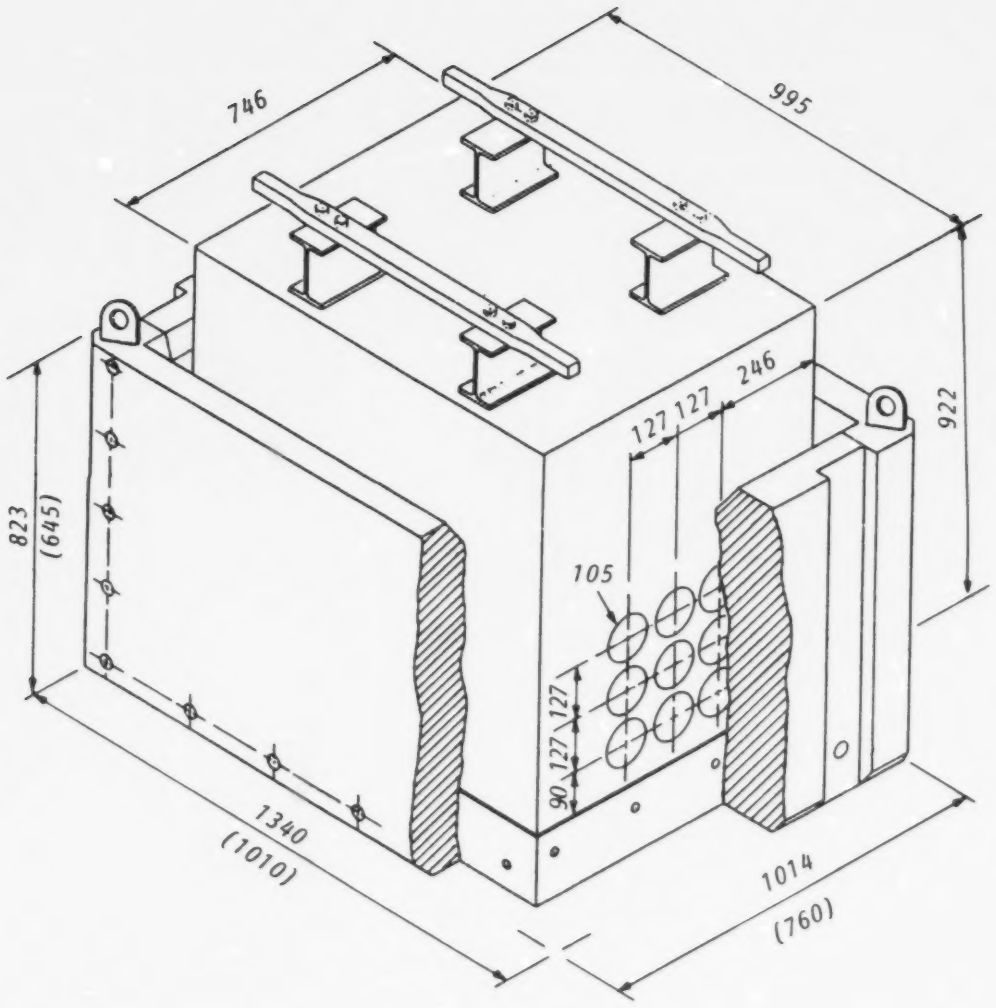


FIGURE 1

SCHEMATIC DIAGRAM OF ROAD CASK FOR RD FUEL



( ) Brackets demote inner surface dimensions

All dimensions in mm

FIGURE 2
CARBON STEEL LINER AND ALUMINUM BASKET
(ACTUAL CASK INTERNALS)

175086-RD

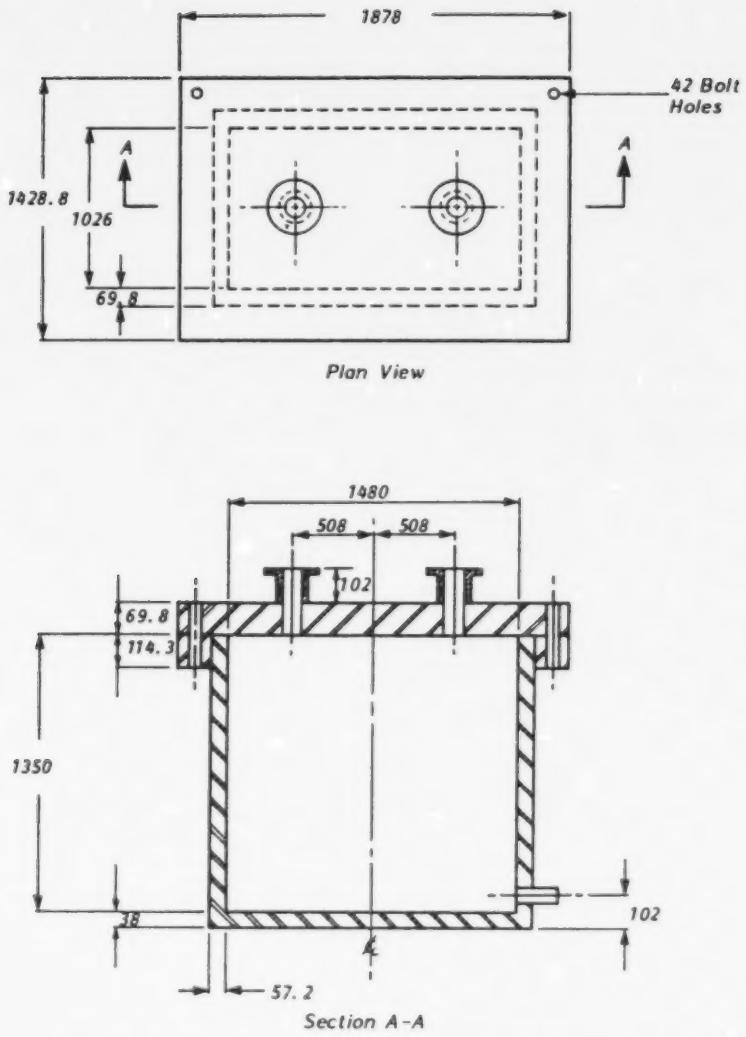


FIGURE 3
SCHEMATIC DIAGRAM OF THE EXPERIMENTAL CASK

175085-RD

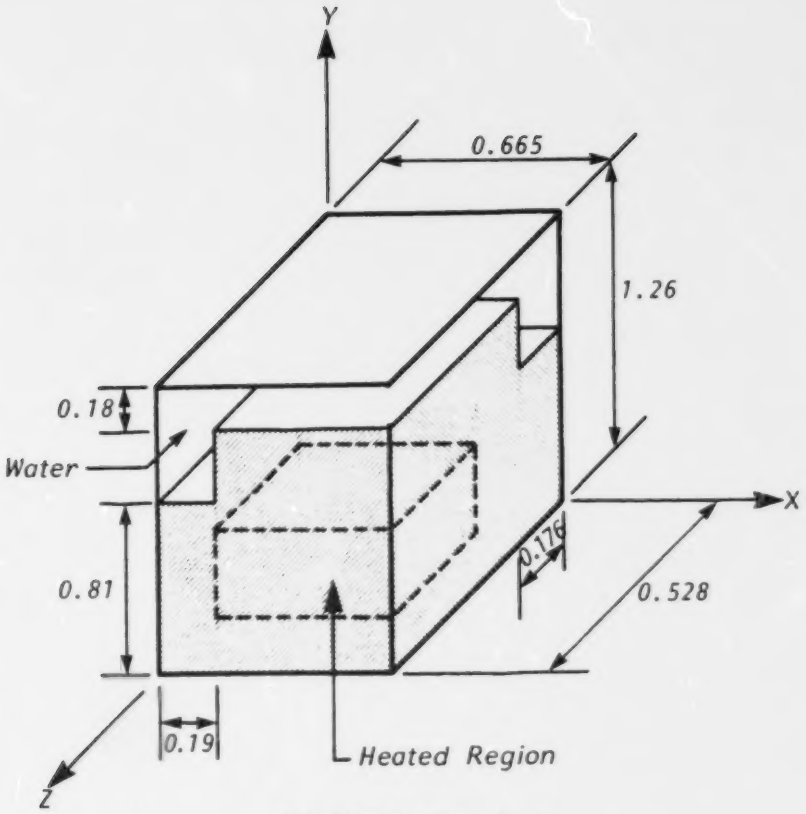
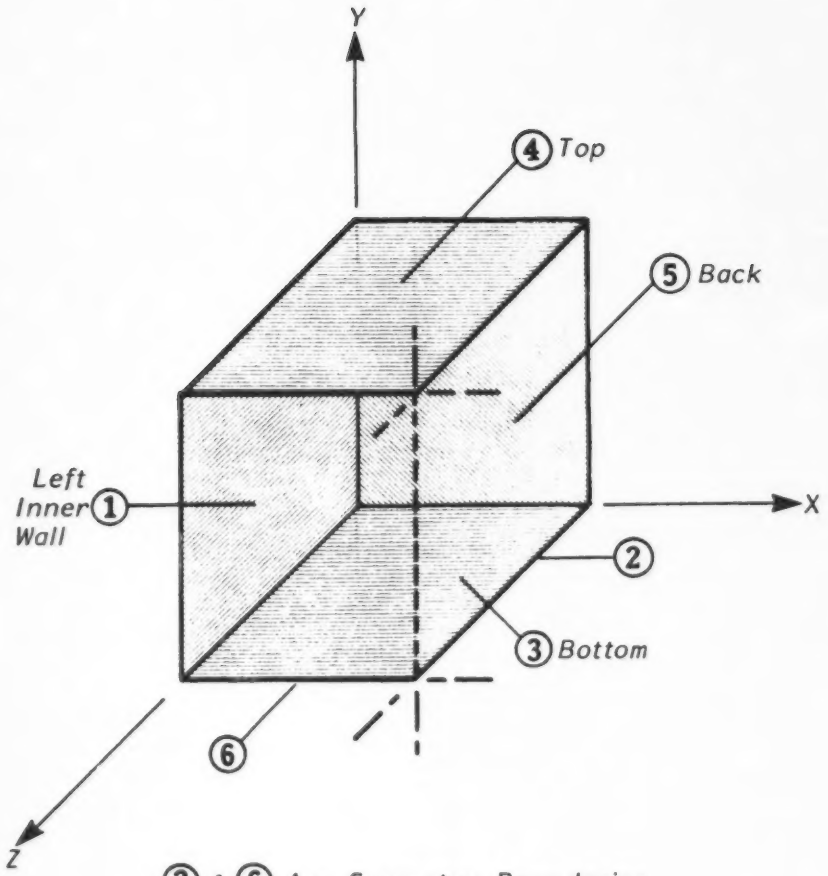


FIGURE 4

DIMENSIONS FOR THEORETICAL MODEL OF EXPERIMENTAL CASK CAVITY



2 & 6 Are Symmetry Boundaries
(Experimental Temperatures not Required)

FIGURE 5

CASK INNER WALLS WHERE EXPERIMENTAL TEMPERATURES /3/
HAVE BEEN APPLIED AS BOUNDARY CONDITIONS

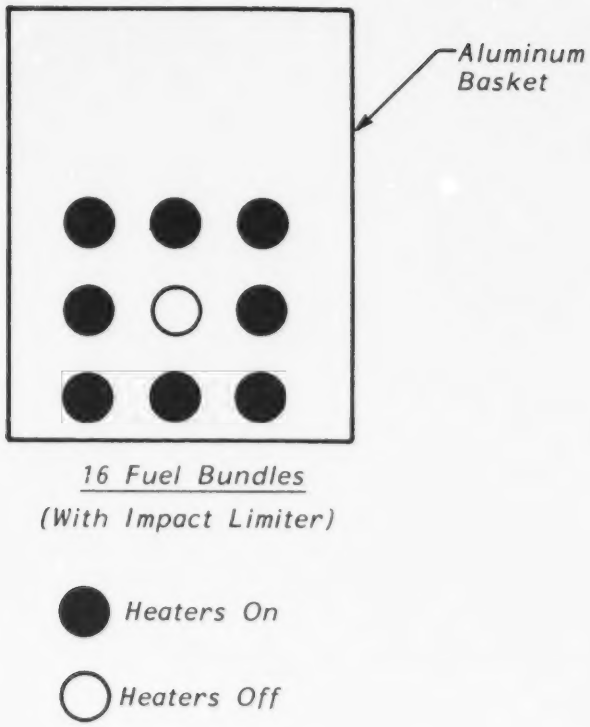


FIGURE 6

TEST CASE USED FROM REFERENCE /3/ FOR
APPLYING TEMPERATURE BOUNDARY CONDITIONS TO THE THEORETICAL MODEL
OF THE EXPERIMENTAL CASK CAVITY

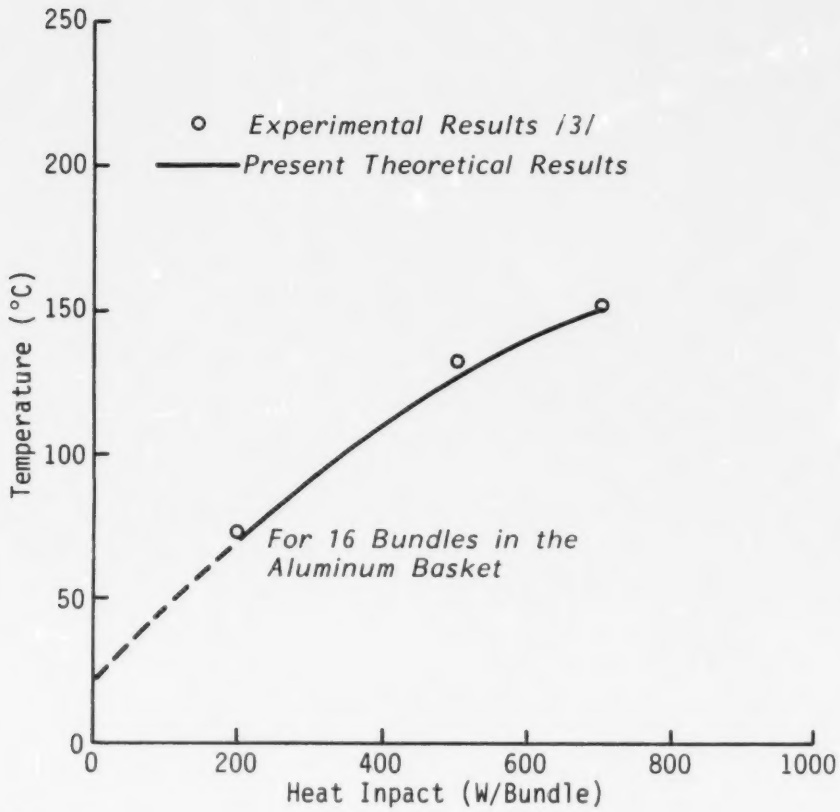
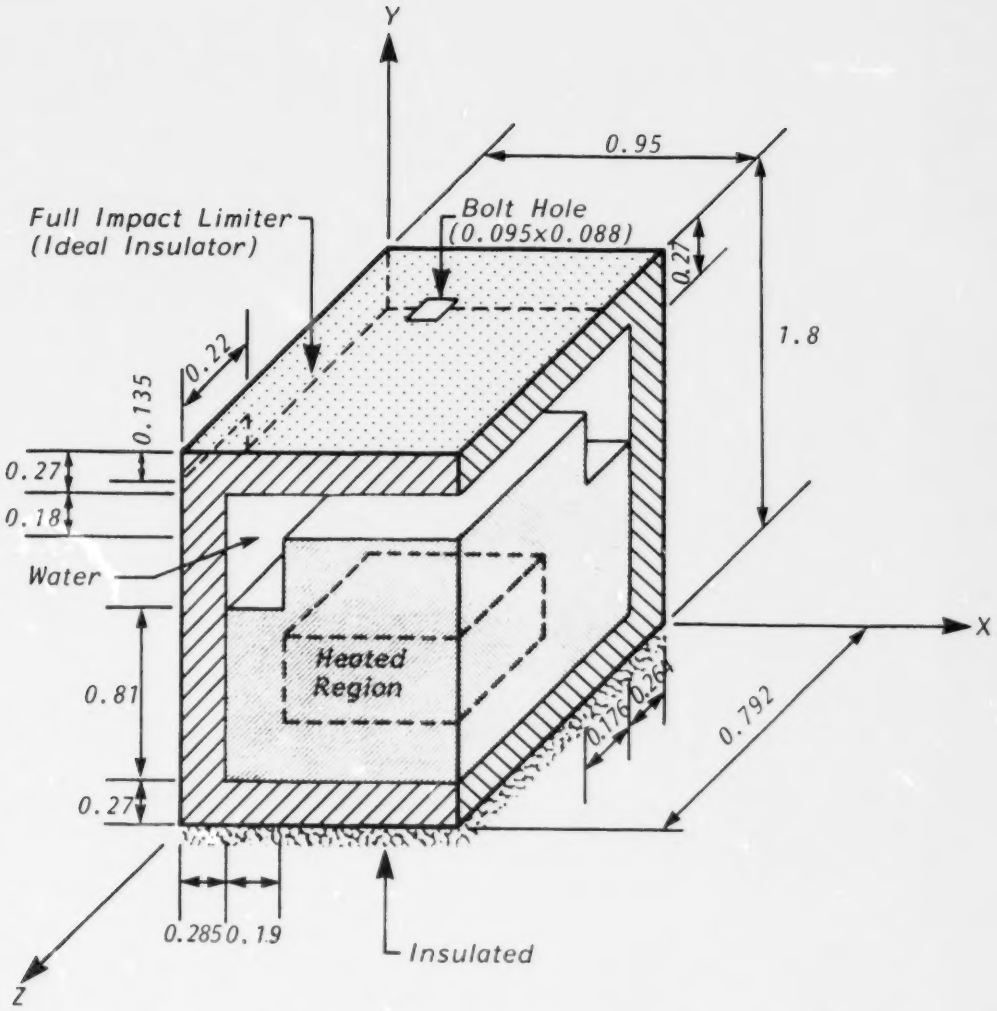


FIGURE 7

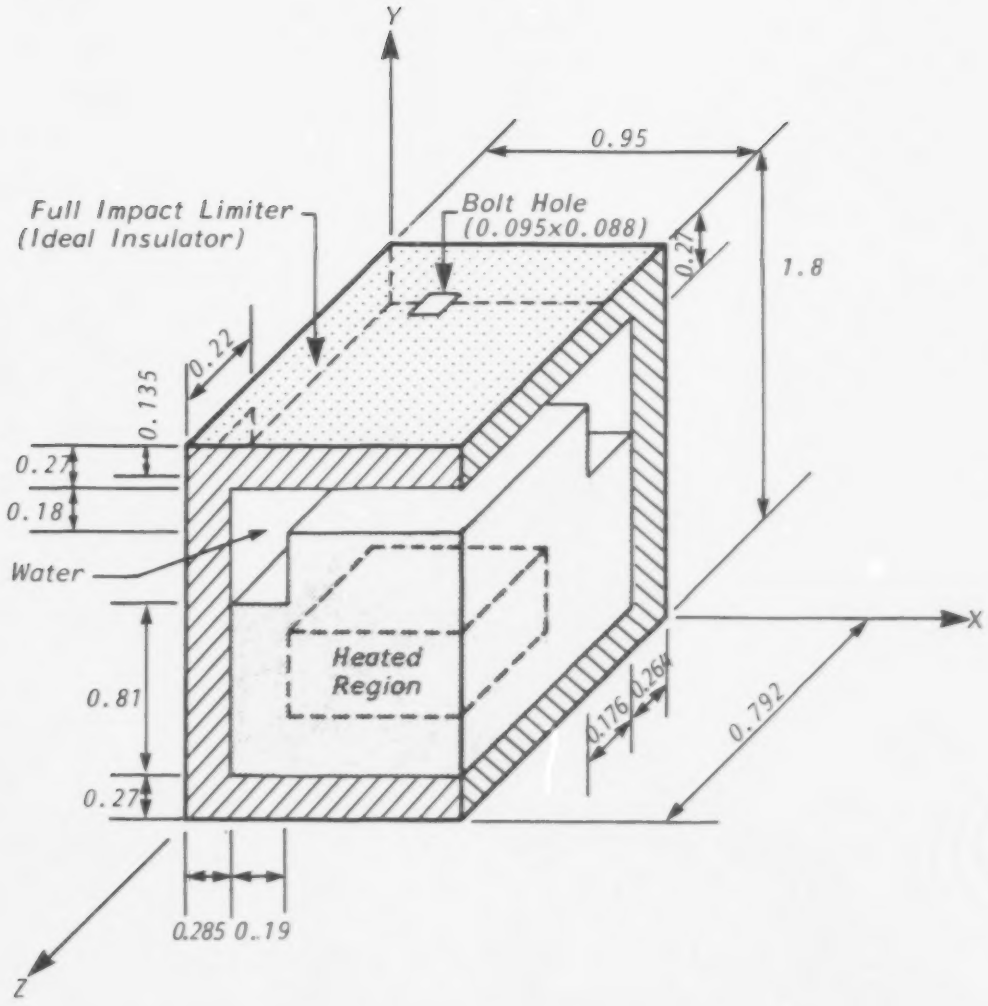
COMPARISON BETWEEN EXPERIMENTAL RESULTS /3/ AND PRESENT THEORETICAL RESULTS FOR THE AVERAGE FUEL BUNDLE TEMPERATURE OF RD FUEL (WATER CAVITY WITH IMPACT LIMITER)



All Dimensions in m

FIGURE 8

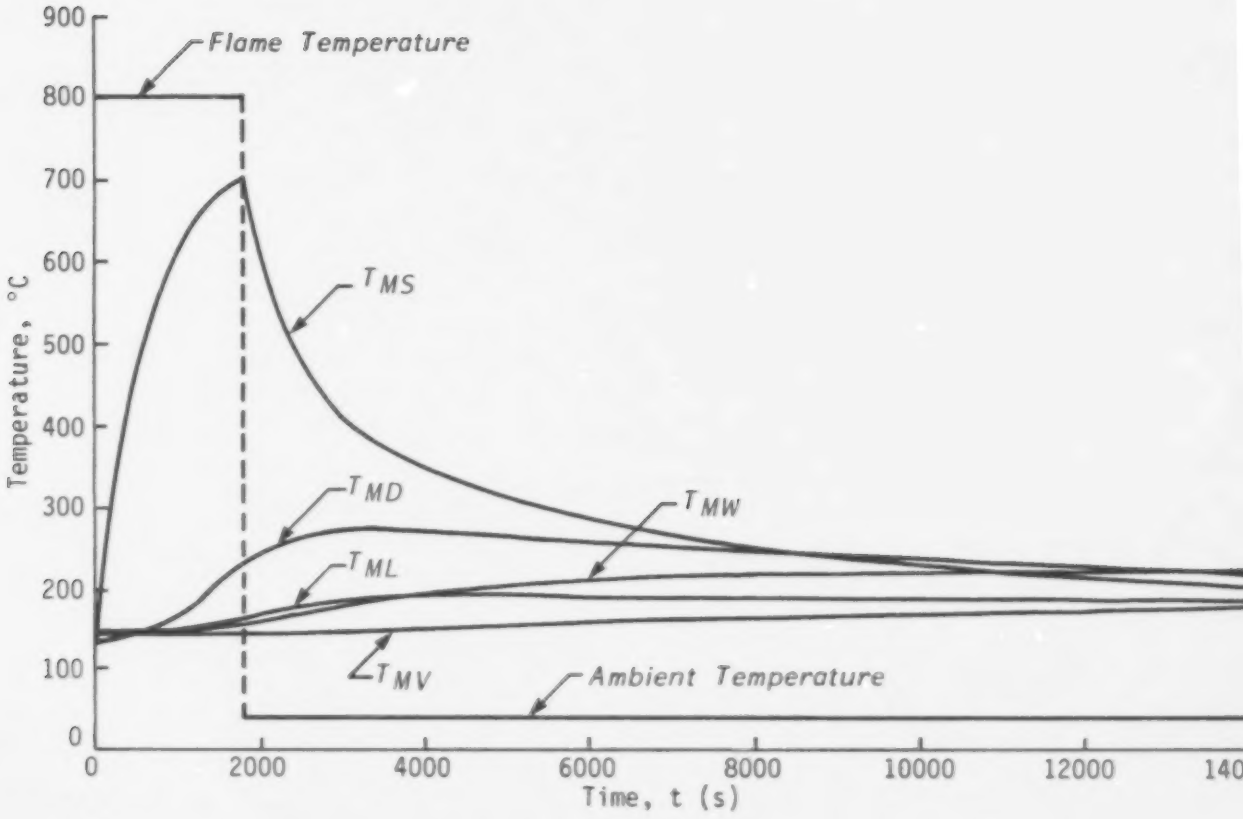
SCHEMATIC DIAGRAM OF MODELLED CASK
UNDER NORMAL OPERATING CONDITIONS
(CASK BOTTOM INSULATED)



All Dimensions in m

FIGURE 9

SCHEMATIC DIAGRAM OF MODELLED CASK
UNDER FIRE ACCIDENT CONDITIONS
(CASK ENGULFED IN FIRE - BOTTOM NOT INSULATED)



T_{MD} = Maximum Drain Seal Temperature

T_{ML} = Maximum Lid Seal Temperature

T_{MS} = Maximum Cask Outer Surface Temperature

T_{MV} = Maximum Vent Seal Temperature

T_{MW} = Maximum Average Cask Inner Surface Temperature

FIGURE 10
FIRE ACCIDENT ANALYSIS RESULTS OBTAINED AT SEVERAL CASK LOCATIONS

TABLE 1

THERMAL PROPERTIES FOR ANALYSIS OF
EXPERIMENTAL CASK CAVITY CONTAINING WATER

ρ (kg/m^3)	C ($J/kg \cdot °C$)	λ ($W/m \cdot °C$)	ν (m^2/s)	β $1/°C$
Simulated Fuel Region				
5312.0	676.9	120.0	-	-
Cavity Fluid - Water				
962.2	4186.8	0.68	3.17×10^{-7}	7.2×10^{-4}

TABLE 2

WALL TEMPERATURE BOUNDARY CONDITIONS OBTAINED FROM EXPERIMENTAL CASK CAVITY CONTAINING WATER AND WITH IMPACT LIMITER/3/

Decay Heat (W/Bundle)	*Cask Inner Wall	Temperature Boundary Conditions (°C)
200	①, ⑤	$T_1 = T_5 = Sy + C$: S = 4.44; C = 61.0 for all Z or X
	③	$T_3 = C$: C = 61.0 for all X and Z
	④	$T_4 = S\,Z + C$: S = 1.97; C = 66.0 for all X
500	①, ⑤	$T_1 = T_5 = Sy + C$; S = 8.88; C = 112.0 for all Z or X
	③	$T_3 = C$: C = 112.0 for all X and Z
	④	$T_4 = S\,Z = C$: S = 1.97 C = 123.0 for all X
700	①, ⑤	$T_1 = T_5 = Sy + C$: S = 10.37; C = 130.0 for all Z or X
	③	$T_3 = C$: C = 130.0 for all X and Z
	④	$T_4 = S\,Z + C$: S = 1.97; C = 143.0 for all X

* See also Figure 5

TABLE 3

THERMAL PROPERTIES - NORMAL

ρ (kg/m^3)	C (J/kg.°C	λ (W/m.°C)	ν (m^2/S)	β 1/°C
Cask Wall - Stainless Steel				
7817.0	460.0	17.0	-	-
Fuel Region				
5312.0	676.9	120.0	-	-
Cavity Fluid - Water				
962.2	4186.8	0.68	3.17×10^{-7}	7.2×10^{-4}

ρ = Density

C = Specific Heat

λ = Thermal Conductivity

ν = Kinematic Viscosity

β = Coefficient of Volume Expansion

TABLE 4

INSOLATION DATA FOR 12 HOURS

* Ambient Temperature, T_A = 38°C
Horizontal Surfaces, $\dot{q}_H$ = 800 W/m²
Vertical Surfaces, $\dot{q}_V$ = 200 W/m²

* Also Used in Analysis Without Insolation

TABLE 5

ADDITIONAL DATA - NORMAL

Cask Exterior Surface Emissivity, ϵ_E = 0.5
Cask Interior Surface Emissivity, ϵ_I = 0.5
Fuel Region Emissivity, ϵ_F = 0.7
Internal Heat Generation, $\dot{Q}_G$ = 99910.0 W/m³ (700.0 W/Bundle)

TABLE 6
SUMMARY OF RESULTS USING TAN-RD (NORMAL) CODE

Results Description	No Insolation	Insolation for 12 h
Maximum Fuel Sheath Temperature T_{MF} (°C)	170.0	170.0
Average Fuel Temperature, T_{AF} (°C)	148.0	148.0
Average Water Temperature, T_{CF} (°C)	147.0	147.0
Maximum Lid Seal Temperature, T_{ML} (°C)	143.0	143.0
Maximum Vent Seal Temperature, T_{MV} (°C)	143.0	144.0
Inside Lid Temperature (at Centre), T_{IL} (°C)	145.0	145.0
Outside Lid Temperature (at Centre), T_{OL} (°C)	144.5	144.5
Maximum Drain Seal Temperature, T_{MD} (°C)	133.8	135.5
Maximum Cask Wall Temperature, T_{MW} (°C)	151.0	151.0
Maximum Trunnion Temperature, T_{MT} (°C)	128.8	131.4
Internal Cask Pressure for Water Cavity, P (kPa)a	618.0	618.0

TABLE 7

THERMAL PROPERTIES - FIRE

ρ (kg/m^3)	C (J/kg.°C)	λ (W/m.°C)	ν (m^2/S)	β 1/°C
Cask Wall - Stainless Steel				
7817.0	500.0	18.2	-	-
Fuel Region				
5312.0	676.9	120.0	-	-
Cavity Fluid - Water				
962.2	4186.8	0.68	3.17×10^{-7}	7.7×10^{-4}

ρ = Density

C = Specific Heat

λ = Thermal Conductivity

ν = Kinematic Viscosity

β = Coefficient of Volume Expansion

TABLE 8

DATA FOR FIRE ENVIONMENT

Fire Flame Temperature, T_{FL} = 800°C
Flame Emissivity, ϵ_{FL} = 0.9
Cask Outer Surface Absorptivity, α = 0.8

TABLE 9

ADDITIONAL DATA - FIRE

Cask Interior Surface Emissivity, ϵ_I = 0.5
Fuel Region Emissivity, ϵ_F = 0.7
Internal Heat Generation, $\dot{Q}_G$ = 99910.0 W/m^3 (700.0 W/Bundle)

TABLE 10
SUMMARY OF RESULTS USING TAF-RD (FIRE) CODE

Results Description	°C	t (s)
Maximum Fuel Sheath Temperature, T_{MF}	230.0	15000
Average Fuel Temperature, T_{AF}	199.0	16200
Average Water Temperature, T_{CF}	197.0	16000
Maximum Lid Seal Temperature, T_{ML}	190.0	4800
Maximum Vent Seal Temperature, T_{MV}	175.0	16200
Inside Lid Temperature (at Centre), T_{IL}	144.9	1800
Outside Lid Temperature (at Centre), T_{OL}	144.5	1800
Maximum Drain Seal Temperature, T_{MD}	269.0	3400
Maximum Cask Outer Surface Temperature, T_{MS}	706.0	1800
Maximum Trunnion Temperature, T_{MT}	406.0	1800
Internal Cask Pressure for Water Cavity, P (kPa)a	2336.0	

t = Time from Start of Fire

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